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COMBINED, LOCAL AND CHEMICAL RADIOPROTECTION DURING SPACEFLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 33 (manuscript received 21 May 82) pp 4-8

[Article by V. I. Yefimov, S. K. Karsanova and V. S. Shashkov]

[English abstract from source] This paper summarizes studies of the combined protection of dogs exposed to acute high energy proton irradiation at a dose of 400 rad. The chemical radioprotector--mexamine--was injected intramuscularly at a dose of 10 mg/kg or administered per os at a dose of 75 mg/kg. During the exposure 14.5% of bone marrow was shielded. The dose behind the shielding was 250 rad. The combined use of mexamine administered per os and partial bone marrow shielding provided better protection, whereas either type of protection applied separately proved inefficient.

[Text] The desire to enhance protection against radiation, with due consideration of available means of drug (pharmacological) prevention, as well as of the effect of local (physical) shielding led to investigation of variants of combined protection of the body. The intent was to obtain a potentiated (additive) radioprotective effect.

Already after the first studies of the effects of local shielding [1] and description of radioprotective agents [2], efforts were made to combine the latter with local shielding of the body in order to enhance the overall radioprotective effect [3-6]. In subsequent years, interest rose in the study of combined protection in view of determination of the mechanisms of action of radioprotective substances on the body, appearance of new protective agents and expansion of research on postradiation recovery and local shielding. Efforts were made to explain the additive effect when a protective agent (or agents) was combined with partial shielding of the body. The thesis was advanced that the outcome of radiation damage from total-body, let alone subtotal, exposure (shielding of part of the body) in corresponding dose ranges depends on the damage to, preservation and restoration of the population of stem cells of critical systems (bone marrow and intestine). This made it possible to analyze the protective effect of radioprotective agents, as well as of shielding, on the cellular level [7, 8].

To date, quite a few experimental studies have been published, which were pursued on small laboratory animals exposed to γ- and x-radiation, as well as radiation from neutrons, where radioprotective agents combined with local shielding were used. Although the experiments were quite heterogeneous with respect to conditions, choice of protective factors and combinations, enhancement of the radioprotective effect was unquestionable [9-15].

In a large series of experiments [16-18], studies were made of the possibility of using shielding of different thickness, width and localization, combined with preradiation administration of cystamine, aminoethylisothiuronium, mexamine or a mixture of protective agents, to protect albino rats exposed to γ-radiation or high-energy protons in doses of 650-1300 rad. Protection was also enhanced when agents were given in reduced (as compared to conventional) dosage and combined with "ineffective" shielding, i.e., when local dose to the shielded region (head or abdomen) constituted about 40% (260-400 rad) of the total exposure dose. While only 2.7-6.3% of the animals survived with use of protective agents and almost 10% survived when the head was shielded, the survival rate was 36-82% when mexamine or cystamine was combined with local shielding. Combined protection was 1.4-2.0 times more effective than shielding alone, when the abdominal region was shielded so that, in addition to intestinal loops, hemopoietic tissue (three lumbar vertebrae and half the spleen) was shielded. The results of the studies revealed that the efficacy of combined protection depends largely on radiation dosage (form of radiation damage), localization of shielding, radiosensitivity of tissues (bone marrow or intestine) in the irradiated field, as well as which radioprotective agent is used.

In the opinion of P. P. Saksonov [19], the potentiating effect of using reduced doses of protective agents combined with "ineffective" shielding of a circumscribed part of the body could be of basic relevance to development of combined protection for use in spaceflights.

The results of experiments performed on small laboratory animals, which are of theoretical interest and have practical implications, served as grounds to investigate this method of protection in experiments on dogs. Moreover, the lack of information in the literature about large mammals or of data concerning the protective effect of mexamine on dogs exposed to high-energy protons, which are among the most important components of cosmic radiation, prompted us to conduct such experiments.

Methods

In our experiments we used 73 dogs (males and females), most of whom weighed 7-9 kg. The synchrocyclotron of the Joint Institute of Nuclear Energy* in Dubna was used to deliver 240 MeV protons. The dogs received a dose of 400 rad. Dose rate was 0.3-1.2 rad/s. We shielded the pelvic region of the dogs with lead blocks 10 cm wide, 10 cm thick and 20 cm high. About 14.5% of all active bone marrow was contained in the shielded region (~15% of total body mass) [20]. Radiation conditions were so selected as to obtain 250 rad under the shield,

*Translator's note: This institute is listed as Joint Institute of Nuclear Research in U. S. reference material.

while the rest of the body (about 85%) received 425 rad.* In all instances, mean tissue absorbed dose was 400 rad.

Mexamine (5-methoxytryptamine hydrochloride) was given in a dosage of 75 mg/kg body weight (scaled to base) through a catheter into the stomach in the form of solution 20-25 min before irradiation, or by intramuscular injection in a dosage of 10 mg/kg 10-12 min before exposure. The animals were kept under observation for 45 days after irradiation. Observation included examination of the animals, weighing them, testing peripheral blood on the 3d, 7th, 10th, 15th, 20th, 25th, 30th and 45th postradiation days using conventional methods.

Results and Discussion

Administration of a protective agent per os or by intramuscular injection was tolerated satisfactorily when given in the indicated dosage. After irradiation, all of the animals (controls and protected) developed acute radiation sickness with similar signs. External signs of disease appeared in the absolute majority of dogs after a latency period of 9-12 days. The animals died from the hemopoietic syndrome of acute radiation sickness. The outcome of irradiation is listed in Table 1.

Table 1. Survival of experimental dogs after acute irradiation from high-energy protons

GROUP	ANIMAL GROUP	NUMBER OF ANIMALS IN GROUP	DEATHS	MST, DAYS	SURVIVAL RATE
1	CONTROL	23	23	13,4±0,4	0
2	SHIELDED	16	14	15,4±0,6	12,5
3	MEXAMINE PER OS	7	7	14,9±1,06	0
4	MEXAMINE PER OS + SHIELDING	11	7	17,9±1,95	36,5
5	MEXAMINE IM	10	10	14,1±0,97	0
6	MEXAMINE IM + SHIELDING	6	6	18,2±1,8	0

Table 1 shows that when the dose delivered to the shielded bone marrow region was 250 rad only 12.5% of the animals survived (2 out of 16 dogs). At the same time, mean survival time (MST) of dogs in this group was reliably longer than the MST for control animals ($P<0.05$). Thus, while 50% of the control dogs expired by the 14th day, only ~7% of those protected with shielding survived (1 out of 14 dogs).

Mexamine given per os (75 mg/kg) or intramuscularly (10 mg/kg) did not increase the survival rate of irradiated animals: in both instances all protected dogs died. With the combined use of mexamine per os followed by shielding, 36.4%

*M. A. Sychkov and A. I. Portman monitored irradiation and dosimetry. We wish to thank them for their assistance in the experiments.

Table 2. Changes in total peripheral blood leukocyte count in control and protected dogs after acute irradiation from high-energy protons (thousands/mm^3; M±m)

Group	Animal group	Initial number of cells	Postradiation day							
			3	7	10	15	20	25	30	45
1.	CONTROL	8,6±0,17	3,1±0,29	1,0±0,08	0,5±0,06	0,2±0,04				
2	SHIELDED	8,3±0,29	3,9±0,28	1,4±0,1	1,1±0,11	0,53±0,07	1,3	3,0	5,0	7,0
3	MEXAMINE PER OS	8,9±0,4	3,5±0,35	1,7±0,21	1,1±0,07	0,6±0,12				
4	MEXAMINE PER OS + SHIELDING	6,5±0,38	2,8±0,17	1,6±0,13	1,3±0,14	1,1±0,15	1,4±0,18	2,3±0,2	3,3±0,39	5,5±0,8
5	MEXAMINE IM	7,9±0,07	2,6±0,24	1,1±0,27	0,7±0,18	0,57±0,14				
6	MEXAMINE IM + SHIELDING	8,0±0,36	2,8±0,8	0,8±0,1	0,4±0,1	0,47±0,12				

of the dogs survived. With use of intramuscular injections and shielding (6th group), although the survival rate did not rise the MST had a a tendency toward increasing, as compared to dogs who were either given mexamine or shielded (5th and 2d groups).

In all experimental groups of dogs there was a decrease in body weight. By the 15th postradiation day, their weight dropped by an average of 7-14%.

Analysis of cellular composition of peripheral blood revealed that leukopenia developed in all dogs (Table 2). We see from the data listed in Table 2 that, already on the 3d day, leukocyte count dropped by more than 50% in all groups of dogs. On the 15th day leukopenia was the most marked in all animals. In protected dogs, leukocyte count was always somewhat higher at this time than in the control (by 1.7-3 times). On the 15th postradiation day, leukocyte count was appreciably higher only in animals given mexamine per os at the rate of 75 mg/kg and protected with shielding (4th group), as compared to control dogs and those given mexamine (3d group) or on which a shield was used (2d group). No analogous finding was demonstrable in dogs given mexamine by intramuscular injection in a dosage of 10 mg/kg with subsequent use of shielding (6th group).

There was equally intensive restoration of peripheral blood leukocytes after the 15th day in surviving dogs. By the 45th day, leukocyte count reached 80-85% of the initial value in all of these dogs.

In all experimental groups of dogs, erythrocyte count began to drop appreciably only starting on the 7th postradiation day. Maximum erythropenia (2.5-4.0 million/mm^3) was observed on the 15th (among dogs that expired) and 20th (survived) days. Already by the 30th day, erythrocyte count rose appreciably in the latter. On the 45th day it constituted ~80% of the base level.

These results indicate that after acute irradiation with high-energy protons in absolutely lethal doses (400 rad), which

elicit the pancytopenic syndrome of acute radiation sickness, the death rate was almost 90% among dogs with local (physical) shielding of ~14.5% of bone marrow in the body (if this region receives a dosage of 250 rad). Apparently, in this case, there is virtually complete loss of compensatory capabilities in the shielded bone marrow region of these animals. Preventive administration of mexamine in the tested doses (10 mg/kg by intramuscular injection or 75 mg/kg per os) also had virtually no effect on the general outcome of irradiation. At the same time, according to our findings, administration of the protective agent per os combined with subsequent shielding of bone marrow, which was aimed at preserving the "critical" pool of hemopoietic stem cells [8], potentiated the radioprotective effect and was considerably more effective than a similar combination with intramuscular injection of the protective agent. Since protection of hemopoiesis is of first and foremost significance to the outcome of the hemopoietic form of acute radiation sickness, it can be concluded that protection with mexamine of hemopoietic stem cells [7] together with cells preserved by shielding during irradiation cause synergism of protection and increase the probability of survival of irradiated dogs.

Thus, on the basis of data in the literature and the results of our experiments, we can conclude that investigation of the combined use of radioprotective agents and local shielding (including the basic possibility of obtaining an additive protective effect in large mammals also, in particular dogs) could be not only of scientific, but practical significance. It is imperative to conduct studies in this direction systematically and purposefully in order to solve the problem of mechanism of combined protection, validate optimum variants of such protection and determine the feasibility of practical use, including application to space radiobiology and medicine.

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UDC: 629.78:612.014.482.5

SOLAR COSMIC RADIATION AND RADIATION HAZARD OF SPACEFLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 14 May 82) pp 8-13

[Article by L. I. Miroshnichenko]

[English abstract from source] Present-day data on the spectrum of solar radiation in the source and near the Earth are discussed as applied to the radiation safety of crewmembers and electronics onboard manned and unmanned spacecraft. It is shown that the slope of the solar radiation spectrum changes (flattens) in the low energy range. Quantitative information about absolute solar radiation fluxes near the Earth is summarized in relation to the most significant flares of 1956-1978. The time-related evolution of the solar radiation spectrum in the interplanetary space is described in quantitative terms (as illustrated by the solar flare of 28 September 1961). It is indicated that the nonmonotonic energy dependence of the transport path of solar radiation in the interplanetary space should be taken into consideration. It is demonstrated that the diffusion model of propagation can be verified using solar radiation measurements in space flights.

[Text] 1. General characteristics and difficulties of the problem. Cosmic solar radiation (SCR) is among the first and foremost sources of radiation hazard from fast charged particles in the orbits of modern manned space complexes (MSC) and unmanned spacecraft (SC). This radiation is generated by solar flares and consists essentially of protons with energy of $\varepsilon_K \geq 10^6$ eV. Appearance of SCR near earth cannot be predicted with sufficient accuracy as yet, although there are several methods that permit evaluation of the different characteristics of radiation (time of particle arrival on earth, maximum flux, spectrum indicator and others).

From the standpoint of assuring radiation safety of crews and electronic equipment of MSC and SC, the range of $\varepsilon_K \approx 20$-500 MeV is of the greatest interest. Quantitative information about the shape of the spectrum at the source (in the sun's atmosphere), absolute particle flux, time and space evolution (dynamics) of particle spectrum in the course of an entire solar proton event (SPE) is needed for accurate assessment of the hazard created by SCR, as well as for planning and conducting experiments in space.

At the present time, there is no systematic theory or even detailed phenomenological information about the behavior of an SPE from the time of its generation to the time of recording it. Acceleration theory is alternative: 1) with various base conditions (different mechanisms of accelerations), the estimated spectrum of accelerated particles could have the same form (for example, exponential, $^{-\gamma}$, $^{-\gamma}$); 2) a specific form of observed spectrum, [for example, exponential function of hardness ~exp $(-R/R_0)$] could correspond to different mechanisms of acceleration; 3) to describe the form of the spectrum in different energy ranges one has to draw upon different mechanisms of acceleration. These contradictions are partially attributable to the insufficient accuracy of measurements, narrowness of energy ranges that can be submitted to a specific method of observation and methodological flaws in reconstructing the spectrum at the source on the basis of observations near earth [1]. At the same time, there is reason to maintain [1] that these theoretical difficulties are fundamental: apparently, there is a combination of accelerating mechanisms at the source which provide for the variable shape of the SCR spectrum with gradual flattening as we go from the high-energy segment of the spectrum to the region of lower energies.

The wide diversity of observed time profiles of intensity of solar protons also creates major difficulties in assessing the conditions under which particles exit from the solar corona and propagate in interplanetary space. The energy and space dependence of parameters of propagation leads to substantial distortion of the observed spectrum, as compared to the SCR spectrum at the source. In order to build a systematic [consistent] theory of SCR behavior, we think it is necessary to have models of propagation based on analysis of the time profiles of SCR supplemented by models of acceleration based on analysis of energy spectra of solar particles. We submit below the most relevant data, in our opinion, about the distinctions of generation of cosmic radiation on the sun, propagation of particles in interplanetary space and evolution of their spectrum (see also the survey in [1]).

2. Spectrum at the source. To date, it has become possible to define source spectra or assess the indicator of the spectrum and integral number of particles with hardness in excess of the specified $N_{\odot}(\geq R)$ for 33 instances of SPE in the 1956-1977 period [1]. Figure 1 illustrates spectra for some SPE according to hardness R. These spectra were obtained by different authors, but in essence by the same method--reconstruction of the spectrum observed near earth with use of some version or other of a diffusion model. The illustrated spectra can be described by one of the following formulas:

$$D_{\odot}(R) = D_0 R^{-\gamma}, \tag{1}$$

$$D_{\odot}(R) = D_0 \exp(-R/R_0). \tag{2}$$

Unfortunately, the accuracy of determining spectral parameters D_0, γ and R_0 is low (a factor of ~2 for D_0, $\Delta\gamma\approx\pm0.5$ and $\Delta R_0\approx\pm0.05$-0.1 GV); the data of different authors pertaining to the same flare do not always agree, while the applicability of the diffusion approach prompts justifiable doubt in some cases. Nevertheless, the data in [1] constituted, to some extent, a homogeneous series, since they were obtained only for events where the diffusion approximation was applicable. With these stipulations, they can be used as base data for calculating the main radiation (dose) characteristics of SCR.

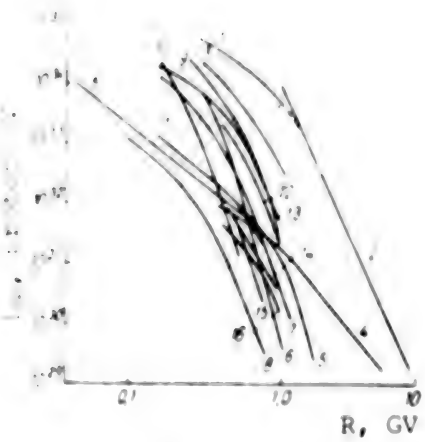

Figure 1.
Differential spectra of hardness of solar protons for SPE's in 1956-1969

1) SPE on 23 Feb 1956-W
2) same on 23 Feb 1956-M
3) 15 Nov 1960-W
4) 28 Jan 1967-M
5) 23 May 1967-M
6) 10 Nov 1961-M
7) 28 Sep 1961-W
8) 23 Oct 1962-M
9) 16 Jul 1959-W
10) 22 Aug 1958-W
11) 3 Sep 1960-B and 25 Feb 1969-B
12) 15 Nov 1960-B and 28 Jan 1967-B
13) 18 Jul 1961-W
14) 4 May 1960-B
15) 28 May 1967-B
16) 30 Mar 1969-B

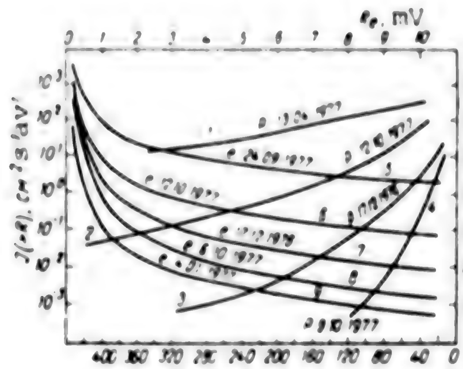

Figure 2.
Integral spectra of hardness of solar protons and electrons for a series of SPE's in 1976-1977. R_p and R_e--hardness in MV units for protons and electrons (top and bottom scales, respectively)

1-4) proton spectra for SPE's on 13 Apr 1977, 12 Oct 1977, 17 Dec 1976 and 9 Oct 1977, respectively
5-9) electron spectra for SPE's on 24 Sep 1977, 12 Oct 1977, 17 Dec 1976, 6 Oct 1977 and 4 Jan 1977

Analysis of the data in [1] enabled us to detect some distinctions in the spectra exceeding the range of the above ambiguities. In particular, it was found that in the exponential expression (1) the spectra have a variable slope, and they become flatter (γ diminishes) in the range of low R's. On the other hand, if the range under consideration is rather broad, exponential expression (2) alone is also inapplicable. This can be well-seen on the example of the events on 23 Feb 1956 and 28 Jan 1967, and it is also confirmed (as a trend) for a number of other SPE's.

The above distinction of the spectra can be interpreted on the basis of a model, in which acceleration is effected by electric field E, which appears upon separation of the neutral current layer, combined with a betatron mechanism. In this case, the source spectrum is described by the following formula [1]:

$$D_s(R) = D_0 (1 + R/R^*)^{-\gamma}. \qquad (3)$$

where D_1 is the normalizing constant, while parameters R* and γ are determined from observations. With $R/R^* \ll 1$, formula (3) is reduced to formula (1), and with $R/R^* \gg 1$, it is approximated quite accurately by equation (2).

The lack of selectivity with respect to kind of particles, effective acceleration of not only protons, but electrons, the close link with the physics of solar flares (through field E) are the obvious advantages of the model in [1]. A similar approach (combination of Fermi and betatron mechanisms) was used, for example in [2], to describe the spectrum of electrons that was reconstructed from observations of electromagnetic radiation of the flare on 4 Aug 1972. With ε_K = 0.01-100 MeV, the spectrum at the source has a variable slope (it becomes flatter with ε_K<1 MeV).

At the same time, models of the [1, 2] type also have flaws, which are related to the ambiguity of conditions in the region of acceleration. Moreover, we also consider quite problematic consideration of the effect of conditions of particle exit from the solar corona, particularly in the range of low energies. In this regard, the indications that, for flares in the heliolongitude range of 20-80°W, the differential spectrum of protons with ε_K = 4-80 MeV at time t_{max} near earth apparently reflects the source spectrum [3] merits attention, and the spectrum parameter changes from flare to flare within a narrow range--2.0-3.1. These conclusions were derived from analysis of SC data for 125 SPE's.

On the other hand, data are cited in [4] about the spectra of electrons with ε_K = 0.03-3 MeV and protons with ε_K = 0.1-500 MeV, which were obtained for time t_{max} according to near-earth observations of 19 SPE's with the help of the SC's Forecast-["Prognoz"] 5, 6, Venus-["Venera"] 11, 12, and IMP-7, IMP-8 in 1976-1979. Typically, the proton spectra for all events presented a more complex appearance than electron spectra, and the proton spectra become more sloped in the range of low energies (experiencing 1-2 breaks). This effect is attributed [4] to adiabatic slowing of protons in the course of their propagation in interplanetary space. In our opinion, stricter validation of the obtained form of spectrum, for both protons and electrons, can be obtained with the model in [1].

After analyzing the data in [4] on the basis of formula (2), we arrived at the conclusion that the spectra of protons and electrons for hardness on a semi-logarithmic scale have the appearance of smooth curves. This is apparent in Figure 2, which illustrates the spectra of several SPE's differing appreciably in intensity (the spectra for the other events have an analogous shape). If the spectra described in [4] are indeed similar to the spectra at the source, it can be stated that their shape is not in contradiction to the acceleration model [2]. Let us note that strict validation of the variable form of SCR spectrum at the source would be of basic significance to assessment of radiation characteristics of SCR.

3. Propagation and evolution of SCR spectrum. In the course of propagation in heterogeneous magnetic fields of the solar atmosphere and interplanetary space, the source spectrum should undergo deformation (with the exception, perhaps, of some limited range of energies [3, 4]). Deformation occurs, specifically, due to the energy dependence of parameters of propagation in the corona (diffusion, convection and drift, see, for example, [5, 6]) or in interplanetary

...ance (transport range for scatter $\Lambda(\varepsilon_k)$ [1, 2]. Because of the dynamic nature of the interplanetary environment, its marked time and space heterogeneity, strict kinetic theory of propagation cannot, for the time being, explain the whole diversity of observed time profiles of SCR, in spite of its well-developed software. For this reason, in many instances, one must give preference to phenomenological theory to interpret SPE characteristics, which is based on the tensor conception of coefficient of spatial diffusion κ_{ij}. Some of the components of this tensor equal zero, while among the others we can single out certain dominant components corresponding, for example, to transport range $\Lambda_{\parallel}$ along the interplanetary magnetic field (IMF). The value of $\Lambda_{\parallel}$ can be either comparable to $\Lambda_{\perp}$, the range across the IMF (isotropic diffusion), or exceed it significantly (anisotropic diffusion).

Table 1.
Λ as a function of ε_k

ε_k, MeV	1	10	10^2	10^3	10^4
Λ, cm	$3 \cdot 10^{12}$	10^{12}	$8 \cdot 10^{11}$	10^{12}	$8 \cdot 10^{12}$

Table 2.
R_0 as a function of hardness range

№	ΔR, MV	R_{0as}, MV	t_t, h	R_0, MV
1	400–1000	161	1,15	208
2	400–500	97	1,4	135
3	500–700	162	1,0	201
4	700–1000	197	1,0	247

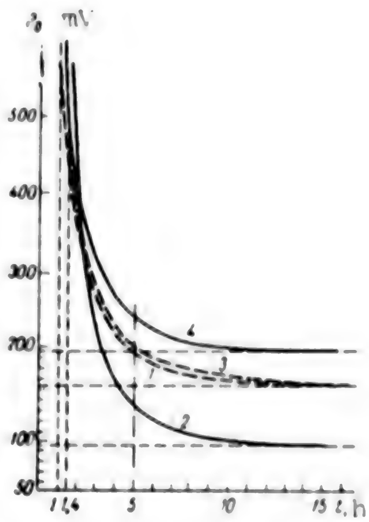

Figure 3.
Characteristic parameter of exponential spectrum R_0 as a function of time for SPE on 28 Sep 1961 in several ranges of hardness ΔR. The numbers near the curves correspond to range numbers in Table 2.

To identify ["diagnose"] an SPE and describe evolution of the spectrum and time profile of SCR, it is important to take into consideration the nonmonotonic nature of function $\Lambda(\varepsilon_k)$: in the interval of ε_k = 30-300 MeV the range has a diffuse minimum (for more details see [1]). None of the propagation models can explain the nature of the minimum as yet. However, for practical purposes, it is important to note that the value of Λ can undergo 5-6-fold change from flare to flare at the same energy in the range of 10-500 MeV. We can use the following (Table 1) as approximate values of $\Lambda(\varepsilon_K)$, in accordance with the data in [1].

In recent years it has been possible to clearly demonstrate an interesting feature in the time dynamics of the SCR spectrum observed near earth, namely, that characteristic hardness of the spectrum R_0 is a function of t when it is expressed exponentially, $D(R) \sim \exp(-R/R_0)$. In Figure 3, function $R_0(t)$ was plotted for data referable to the flare on 28 Sep 1961 for several ranges of hardness ΔR (Table 2).

Figure 3 shows that $R_0(t)$ becomes a smooth declining function of t only when it starts to have a threshold value t_t = 1 and 1.4 h, respectively, for ranges 1 and 3-4 (vertical dash lines). With $t \gg t_t$, function $R_0(t)$ gradually approaches a certain asymptotic value R_{0as} (horizontal dash lines). The vertical dot and dash line shows time t = 5 h, for which there is the experimental value R_0 = 210 MV (averaged for the range of 400-1000 MV), which conforms well with the estimated value R_0 = 208 MV [7]. Analogous behavior of $R_0(t)$ was found in [8] for protons with E_p<24 MeV (R<210 MV) during the SPE's on 7 Sep, 13 Sep and 17 Sep 1973.

The values of R_{0as} in Figure 3 apparently correspond to the established state of SCR flux, when the shape of the spectrum undergoes virtually no change with general decline of intensity. We were impressed by the fact that the value of R_{0as} depends on the width of the ΔR interval considered. This means that the exponent for description of the spectrum is merely a convenient form of approximation, and the narrower a given ΔR interval, the more precise it is.

Results of the type cited in [7, 8] can be used for operational evaluation of magnitude and dynamics of irradiation from SCR according to ongoing readings aboard the SC. Moreover, they indicate a possible route for checking experimentally the diffusion models. It is also apparent from the foregoing, as well as previous findings [7], that for practical estimates it is expedient to first give a forecast of the time course of differential intensities of SCR by a certain time t on the basis of the results of current measurements, and then to reconstruct the spectrum by means of interpolation according to the intensity values obtained by that time.

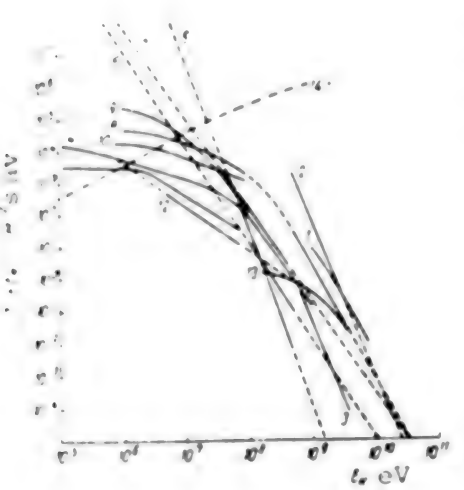

Figure 4.
Integral energy spectra of SCR according to observations near earth at different stages of SPE (solid lines) and possible extrapolation in adjacent energy ranges (dash lines)

1-4) event on 23 Feb 1956, initial phase, 5.00 UT, 20.00 UT and late phase, respectively
6) 15 Jul 1959, 00.30 UT before storm
7) same, 10.46 UT during storm
8) 12 Nov and 15 Nov 1960, t_{max}
9) 12 Jul 1961, t_{max}
10) 18 Jul 1961, t_{max}
11) 22 Nov 1977, t_{max}
12) 7 May 1978, artificial earth satellite, t_{max}
13) same, SNM+strat., t_{max}

Dot-dash line 14 corresponds to equality of energy densities of SCR and geomagnetic field ($B^2/8\pi$ = ($\rho V^2/2$) of SCR.

4. SCR spectra near earth. Different methods of observing SCR (on earth's surface, in the stratosphere, in orbits of artificial earth satellites, along

(on routes of SC in interplanetary space) make it possible to overlap the ranges of measured energies. It thus becomes possible to mutually supplement and verify data about spectra obtained by different methods. Information about the observed SCR spectra near earth is quite extensive and diverse (see, in particular, [1]), but has not yet been summarized or analyzed to the extent necessary to comprehend the physics of propagation of SCR evolution of its spectrum, proper calculation of geophysical effects of SCR and estimation of their dose characteristics. One of the tasks in this area of research is to follow the dynamics of change in absolute flux and shape of SCR spectrum over a wide range of energies (1-10^4 MeV) and throughout the event for a concrete, high-energy SPE, according to the results of synchronous measurements by different methods. We examined data about near-earth spectra for several of the strongest SPE's as the first step toward performing such a task (Figure 4). The solid lines in Figure 4 show the actual spectra observed by some method or other and the dash lines their possible extrapolation to adjacent energy ranges; the dot-dash line corresponds to the condition of equality of SCR energy densities and geomagnetic field (to the left and above this line, the SCR energy density exceeds that of the geomagnetic field, so that SCR can collectively invade the magnetosphere to a certain depth).

Figure 4 shows that the observed spectra, like source spectra, demonstrate a variable slope with flattening in the region of low ε_K over a wide range of considered energies. The data in Figure 4 confirm the known fact that the most powerful of the observed SPE's was the flare on 23 Feb 1956. However, typically enough, even in this instance, the geomagnetic effect of SCR (collective effect of SCR on the geomagnetic field) was apparently insignificant, due to the appreciable flattening of the spectrum in the range of low ε_K. The data in Figure 4 indicate also that the strongest SPE's of the current, 21st cycle of solar activity (22 Nov 1977 and 7 May 1978) were appreciably weaker than the SCR of the 19th cycle (23 Feb 1956, 12 Nov and 15 Nov 1960); SPE's were even weaker in the 20th cycle [1]. Although the illustrated SPE spectra do not conform to one another in their details, the data in Figure 3 could be used as approximate top estimates of SCR flux observed in earth's orbit. Several arguments have been advanced [9] in favor of the assumption that there could be extremely powerful solar flares with total energy emission of up to 10^{36} erg during powerful cycles of solar activity (such as the 19th). Here, about 50% of the indicated energy is discharged, according to estimates in [9], in the form of SCR with ε_K>10 MeV which, in turn, should lead to very marked increase in SCR energy density near earth. According to current estimates, the total energy of a flare is close to 10^{32} erg, and apparently no more than 10% is referable to SCR. From the standpoint of SCR observations pursued now for 40 years, the situation discussed in [9] is apparently purely hypothetical for the time being.

A detailed description of the data illustrated in Figures 1-4 and more comprehensive analysis of these data is beyond the limits of this paper. However, it can be maintained that, in discussing formation and evolution of the spectrum as the key issue in the entire SCR problem, we have come closer to clearer understanding of the phenomenology of generation and propagation of SCR in the first place, and in the second place we gain real quantitative information that is needed to solve the problem of assuring radiation safety of manned and unmanned spacecraft.

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STUDIES OF CHARACTERISTICS OF SOLAR COSMIC RADIATION ON METEOR SATELLITES

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[Article by N. K. Pereyaslova, M. N. Nazarova and I. Ye. Petrenko]

[English abstract from source] The paper presents the results of examinations of solar cosmic rays recorded during 1969-1978 by Meteor satellites in the high latitude areas of the Earth magnetosphere. The purpose of the investigations is to develop methods for diagnosing and predicting the radiation environment in the near-Earth space. Morphological features of proton events, and their relationship with the characteristics of the source and the flare, the state of the interplanetary space and the magnetosphere are described.

[Text] During the period from 1969 to 1978, 73 events of solar cosmic radiation (SCR), in which the flux of protons with energy E_p>5 MeV at the peak of the event exceeded 10 proton•cm^{-2}s^{-1}, were recorded aboard the Meteor artificial earth satellite in the high-latitude regions of earth's magnetosphere. During the peak of the 20th cycle (1969-1970) there were 8 such events recorded, with 23 in the decline (1971-1974), 6 during the years of minimum (1975-1976) and 36 during the build-up of the 21st cycle (1977-1978).

Methods

Build-up of SCR is identified with particle sources. The criteria of choice were both the intrinsic characteristics of the flares and dynamic features of rises in SCR. In searching for the source of injection, we considered the characteristics of flares in M_α of radiowaves of types II and IV, bursts of x-radiation. As a rule, the flares associated with multicomponent bursts of the 4th type (such bursts were indicative not only of particle acceleration, but exit of SCR from the corona) were sources of the observed protons. Examination of a set of features enabled us to identify 90% of the increases in SCR with flares on the sun. Subsequent comparison of results of SCR observations to the source showed that there was good agreement with previously obtained findings [1]. In the period in question, flares in the northern hemisphere of the sun were sources of the largest number of SCR events.

Characteristics of proton events

Flares in H_α: start date	Flares in H_α: start time, h, min	coordinates $\varphi°$	coordinates $\lambda°$	score	Maximum of SCR event: date	time, h	flux $I(E_p>5\,MeV)$ $cm^{-2}s^{-1}sr^{-1}$	spectrum paramet. γ	asymmetry A, %	sign of IMF sector	Maximum asymmetry: date	time, h, min	A, %	IMF	H_α	Amplitude of Alert (1969-76) Apatity (1977-78)
30/III 1969	03 32	N19	W90	1N	30/III	21	$1,1\cdot10^{2}$	1,1	+1,4	+	30/III	06 30	−31	−	N	+[illegible]
10/IV 1969	01 10	N11	E90	1N	13/IV	<18	$>5,3\cdot10^{3}$	3,4	−2	−	11/IV	18 00	−6	−	−	−
30/V 1970	02 18	S08	W30	2B	30/V	21	$1,3\cdot10^{2}$	3,7	+17	+	30/V	11 35	+55	+	N	−
25/VI 1970	18 33	N10	E11	2B	26/VI	08	$8,0\cdot10^{1}$	3,9			26/VI	08 35	+80	−	N	−
12/VIII 1970	20 21	N11	E90	1B	15/VIII	02	$1,9\cdot10^{2}$	3,5	−4	−						−
13/VIII 1970	14 06	N12	E83	2B	15/VIII	11	$4,0\cdot10^{2}$	4,2	+17	+	16/VIII	09 38	+18	−	S	−
1/IX 1971	—	S11	W120	—	2/IX	>03	$>6,2\cdot10^{3}$	1,1	−7	−	1/IX	21 38	−23	−	N	+11
3/X 1971	13 30	N13	E14	2N	3/X	>17	$>7,0\cdot10^{0}$	1,1	+5	−	3/X	16 17	+35	−	S	−
18/IV 1972	00 56	S12	E47	1B	18/IV	07	$1,7\cdot10^{2}$	3,0	−62	−	18/IV	03 40	−72	−	S	−
2/VIII 1972	20 06	N13	E28	2B	4/VIII	>04	$>8,0\cdot10^{3}$	3,9			4/VIII	00 15	+10	+	S	−
2/VIII 1972	18 39	N14	E26	1B	3/VIII	23	$2,0\cdot10^{4}$	—	+3	+	3/VIII	22 34	+4	+	—	−
4/VIII 1972	06 17	N14	E08	3B	4/VIII	16	$1,6\cdot10^{4}$	2,4			4/VIII	09 34	−20	−	S	+15
7/VIII 1972	14 49	N14	W37	3B	8/VIII	02	$3,1\cdot10^{4}$	1,8	−12	−	7/VIII	22 07	−3	−	N	+5
7/IX 1973	11 41	S18	W46	2B	7/IX	14	$1,8\cdot10^{2}$	2,0	+12	+	7/IX	13 37	+60	+	S	−
2/VII 1974	08 01	S1[illegible]	E08	2B	3/VII	16	$3,2\cdot10^{1}$	2,3			3/VII	15 37	+27	+	S	−
4/VII 1974	13 38	S16	W08	1B	5/VII	16	$3,8\cdot10^{3}$	3,2			5/VII	15 28	−47	−	S	−
10/IX 1974	21 21	N10	E61	2B	13/IX	01	$2,6\cdot10^{2}$	2,6	−16	−	12/IX	16 29	−45	−	S	−
22/IX 1974	00 21	N13	W90	1B	24/IX	20	$1,5\cdot10^{2}$	2,3	−15	−	23/IX	03 26	−30	−	—	−
22/VIII 1975	01 08E	N27	W81	1B	22/VIII	04	$3,7\cdot10^{1}$	2,2	+2	+	22/VIII	03 10	−6	−	N	−
27/III 1976	19 05	S07	E28	1B	28/III	<20	$>6,6\cdot10^{0}$	5,5	+12	−	28/III	21 12	+12	−	S	−
30/IV 1976	20 47	S08	W46	2B	30/IV	23	$4,8\cdot10^{2}$	1,8	−10	−	1/V	02	−20	−	—	+1,5
16/IX 1977	21 23	N07	W20	2N	17/IX	02	$6,4\cdot10^{1}$*	0,8								+1,6
19/IX 1977	09 55E	N08	W57	3B	20/IX	05	$3,6\cdot10^{4}$	1,3								+8
24/IX 1977	—	N10	W130	—	24/IX	17	$1,6\cdot10^{2}$	2,2								+15
22/XI 1977	09 45	N24	W40	2B	22/XI	14	$2,8\cdot10^{2}$*	1,2								
13/II 1978	01 15	N15	W20	2N	14/II	11	$2,9\cdot10^{4}$	2,9	+18	+	13/II	09 22	−49	−	S	−
8/IV 1978	01 19	N19	W11	2B	8/IV	06	$7,0\cdot10^{0}$	4,4	+10	+	8/IV	02 50	+20	−	−	−
11/IV 1978	13 34	N22	W56	2B	11/IV	23	$9,3\cdot10^{1}$	1,7	+1,3	+	11/IV	20 34	+22	+	S	−
17/IV 1978	09 19	N14	W22	SB	17/IV	13	$2,9\cdot10^{1}$	1,9	−2	−	17/IV	11 54	+74	+	−	−
28/IV 1978	13 01	N22	E38	3B	29/IV	19	$9,3\cdot10^{1}$*	2,0	−6	−	28/IV	19 56	−14	−	S	−
30/IV 1978	14 20	N28	E14	3B	30/IV	22	$3,8\cdot10^{3}$	2,6	−6	−	30/IV	18 52	+10	−	S	−
7/V 1978	03 27	N23	W72	1N	7/V	06	$5,4\cdot10^{4}$	1,3	+18	−	7/V	05 32	+18	+	−	+39
22/VI 1978	16 43	N18	E16	2B	25/VI	01	$2,4\cdot10^{3}$	4,4	−13	−	22/VI	23 3[illegible]	−52	−	S	−
11/VII 1978	10 31	N18	E45	2B	13/VII	12	$1,6\cdot10^{2}$	4,2	−20	−	12/VII	09 5[illegible]	−61	+	−	−
23/IX 1978	09 44	N35	W50	3B	23/IX	17	$3,2\cdot10^{4}$	2,6	+12	+	23/IX	15 20	−13	+	S	+10
16/X 1978	21 42	N32	E47	1B	17/X	19	$1,1\cdot10^{1}$	3,9	−18	−						
10/XI 1978	00 48	N17	E01	2N	10/XI	24	$1,1\cdot10^{4}$	5,7	−20	−	10/XI	10 19	−32	−	−	−

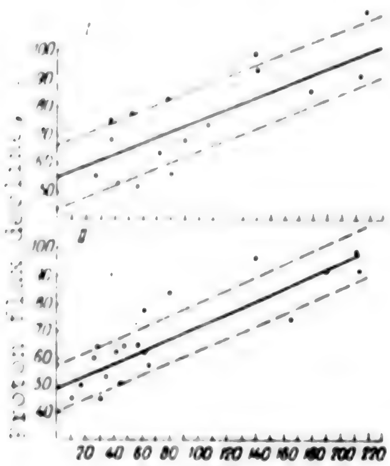
*Proton flux with E_p>15 MeV. Note: Time is universal (UT).

Results and Discussion

The Table lists the characteristics of 37 events recorded aboard Meteor satellite in 1969-1978, in which significant asymmetry and a high integral proton flux over the entire event were observed. The amplitude of asymmetry was calculated using the formula:

$$A = \frac{I_N - I_S}{I_N + I_S} \cdot 100\%$$

where I_N and I_S are averaged intensity in the north and south polar zones. Of the events listed in the Table, an increase in readout rate on neutron monitors was observed on earth in only 10 instances, and maximum amplitude (+39%) was recorded on 7 May 1978.



Amplitude of D_{st} variation, nT

Figure 1.
Change in flux of protons with E_p>10 MeV and E_p>15 MeV as a correlative function of amplitude D_{st} = variations during period of main phase of magnetic storm

I) Meteor satellite (E_p>15 MeV)
II) Explorer satellite (E_p>10 MeV)
The dash lines indicate 95% confidence intervals.

The hardest spectrum (γ = 0.8-1.3) was observed on 30 March 1969, 1 September and 3 October 1971, 16 September, 19 September and 22 November 1977, and 7 May 1978. The most intensive SCR event was on 4 August 1972, when the flux of protons with E_p>5 MeV reached a maximum of $I_{max} = 1.6 \cdot 10^5$ cm^{-2}s^{-1}av^{-1}. The table shows that there was noticeable asymmetry of proton flux. Maximum initial asymmetry was recorded at the stage of buildup of SCR flux. Asymmetry reached maximum amplitude in the event of 26 June 1970, when A = +80%. At the peak of the event, the amplitude was lower and reached ~20%, with the exception of the SCR event on 18 April 1972, when even at the maximum of the event the amplitude of asymmetry remained rather high--A = -62%. Events referable to the phase of buildup of solar activity in the 21st cycle had a hard spectrum; they presented prolonged asymmetry (for example, in the events of 13 Feb 78 [2] and 23 Sep 78, asymmetry was observed throughout the event [3]).

When powerful interplanetary shock waves generated by solar flares passed, along with registration on earth of a storm in SC there was drastic decline in intensity of solar cosmic rays, which was related to elimination [sweeping out] of proton flux by the shock wave front. In 1969-1979, this effect was recorded in 19 events, flux of protons with E_p>10 MeV decreased to 2/5ths to 1/80th the previous value. Figure 1 illustrates changes in flux of protons with E_p>10 MeV and E_p>15 MeV during the period of the main phase of the magnetic storm with SC as a correlation function of D_{st} variation. With increase in D_{st} variation there is increase in degree of removal of proton fluxes (coefficients of correlation are 0.85 and 0.71). The obtained function can be rendered as follows:

$$= 49.6 + 0.22\,D_{st};\ (E_p \cdot 10\ \text{MeV});\ \delta I = 54.7 + 0.19\,D_{st};\ (E_p \cdot 15\ \text{MeV})$$

The large-scale interplanetary magnetic field (IMF) exerts a significant influence on the time and space characteristics of SCR. It was previously shown [3-5] that the north-south asymmetry observed at the first phase of the event is related virtually one-to-one to the direction of the radial component of the IMF. However, SCR events have been recorded where this link is impaired [3, 6]. As a rule, this is observed during magnetic disturbances. The demonstrated impairment of the link between sign [direction?] of asymmetry and sign of the IMF sector during magnetic storms is apparently attributable to the effects of magnetospheric processes and, in particular, redistribution of energy in flux systems. During registration of events, in which significant amplitude of north-south asymmetry was observed, the normal component H_z of the magnetic field was oriented to the south (the direction of the H_z component was determined on the basis of the score of the planetary K_p index obtained by the method proposed in [7]). In 80% of the events considered, increase in flux of protons with energy E_p 5-10 MeV began on the 1st-3d day after the earth intersected the boundary between sectors [4].

During the period of anisotropic propagation of proton flux, there is heterogeneous distribution of particles in polar zones. In several events, there were polar, auroral and cusp ["kasp"?] type peaks on the latitude profiles of particles above the polar caps.

The structure of the observed distribution of particles in polar zones can be explained with models that utilize the mechanism of both diffusion penetration of particles into the magnetosphere and direct passage thereof into the high-latitude region through the tail and along the plasma layer of earth's magnetosphere [8, 9].

Penetration of SCR into the central regions of polar caps at invariant latitudes of ≥80° (formation of polar peaks) is related to movement of particles within the magnetosphere along the open force lines of the tail, when they are reconnected to the force lines of the IMF. With anisotropic distribution of SCR in a quasiregular IMF, there is north-south asymmetry of proton flux in polar caps depending on the orientation of the radial and vertical components of IMF and conditions of reconnection with force lines of the magnetosphere.

SCR protons get into the auroral regions as they move along the force lines of the plasma layer. The polar boundary of penetration of solar protons on the night side of the auroral region coincides with the boundary of the region of closed force lines, and it is a projection of the outer boundary of the plasma layer of the tail of the magnetosphere, on the day side it coincides with the boundary of the polar cusp. The low-latitude boundary of the auroral region is determined by the position of the last closed line of force on the night side of the magnetosphere. After getting into the auroral region along the force lines of the plasma layer, SCR protons form auroral peaks, the position of which depends on the last closed line of force on the night side of the magnetosphere. After reaching the auroral region along the force lines of the plasma layer, SCR protons produce auroral peaks, the position of which depends appreciably on proton energy and geomagnetic disturbance. A comparison

of proton intensities at the maximum of auroral peaks at close local times revealed that these intensities are equal, i.e., penetration of particles through the plasma layer into the northern and southern auroral regions occurs symmetrically.

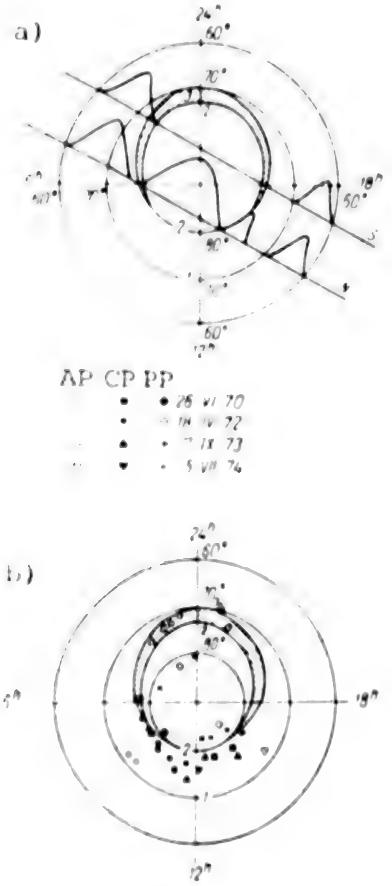


Figure 2.
Position of peaks for protons with energy E_p>90 MeV along the satellite's orbit over the northern and southern polar caps (a) and maximums for protons with E_p>MeV [number missing from source, should be 5 MeV] (b) as a function of invariant latitude and local magnetic time

1) last closed shell
2) last closed force line of geomagnetic field
3) projection of neutral layer

AP) auroral peaks
CP) cusp peaks
PP) polar peaks

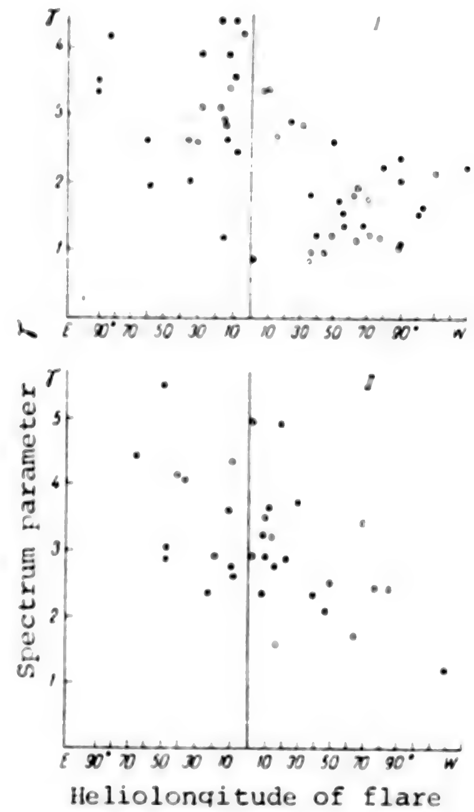


Figure 3.
Parameters of hardness of proton spectrum at maximum of SCR events as a function of heliocoordinates of flare. Black circles--Meteor satellite; white--Explorer.

I) north
II) south

The peaks observed in spatial distribution of protons at invariant latitudes of 76-78° on the day side of the magnetosphere are due to penetration of SCR near the neutral points in the polar cusp region.

Figure 2a illustrates schematically the positions of peaks observed for protons with E_p>90 MeV along the satellite's orbit over the northern and southern

hemispheres. The polar peaks for protons with these energies at a latitude of >78° were first recorded aboard Meteor satellite during the event of 7 September 1973. Figure 2b shows the positions of maximums in latitude distributions of flux of SCR protons with E_p>5 MeV as a function of invariant latitude and local magnetic time. We see that, for all events in question, the maximums are grouped in regions of invariant latitudes of 69-73°, 76-78° and >80°, in accordance with model conceptions of penetration of SCR protons into the magnetosphere.

Data concerning proton flux in the energy ranges of 5-90 MeV (Meteor artificial earth satellite) and 10-60 MeV (Explorer artificial earth satellite) were examined to study the spectral distribution of SCR. The spectra were approximated by an exponential law $I(>E_p) \sim I_0 E^{-\gamma}$. A study was made of hardness of the integral spectrum of protons as a function of SCR proton flare-source coordinates (Figure 3). Spectrum parameter γ changes in the range of 0.8-5.5 with change in γ in the range of 90°E<λ<90°W, and the spectra of protons from flares in the western hemisphere of the sun are harder than from the eastern hemisphere ($\gamma_{av.NW}$ = 1.8; $\gamma_{av.NE}$ = 3.1; $\gamma_{av.SW}$ = 2.7; $\gamma_{av.SE}$ = 3.8), and those from flares in the southern hemisphere are much softer than from the northern. The nature of change in γ_{max} from heliocoordinates of the injection source is attributable to mechanisms of propagation of SCR in the sun's atmosphere and interplanetary space. In the region of 30-60°W longitudes, the dissemination of SCR toward earth occurs primarily along the fibers of a quasiregular IMF at rates corresponding to proton energy. In this case, when maximum flux is recorded the spectrum parameter is usually at a minimum. With propagation of protons from flares in the eastern hemisphere of the sun, the SCR spectrum is much softer, and this can be attributed to diffusion propagation of protons transversely to the force lines of the magnetic field. The propagation of protons from the source beyond the shock wave front [10, 11] or in magnetic traps of the Gold's bottle type [12] also leads to softening of the SCR spectrum. The differences in spectral characteristics of SCR events from flares in the northern and southern solar hemispheres are probably attributable to the structure of the overall magnetic field of the sun. The extended flux [current] layer formed as a result of interaction between the sun's global magnetic field and plasma of solar wind could also serve as an obstacle to dissemination of particles from flares in the southern hemisphere of the sun [13, 14]. In addition, the structural distinctions of the coronal magnetic field [15] could have an appreciable effect on the spectral characteristics of SCR.

The results of the studies revealed that there is a link between time-and-space and spectral characteristics of SCR the direction and structure of solar magnetic fiels, interplanetary space and geomagnetic field. Determination of the mechanisms of propagation of SCR from the source and penetration into near-earth space and earth's magnetosphere makes it possible to take into consideration the obtained patterns in methods of forecasting the radiation situation.

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EVALUATION OF STATISTICAL CHARACTERISTICS OF SOLAR COSMIC RADIATION FLARES IN TWENTIETH AND TWENTY-FIRST CYCLES OF SOLAR ACTIVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 14 May 82) pp 18-23

[Article by S. G. Frolov]

[English abstract from source] This paper presents the principal characteristics of solar cosmic radiation events in the 20th and 21st cycles of solar activity. A uniform row of data concerning solar cosmic radiation has been obtained. An analysis of large-scale variations of the proton intensity time profile has demonstrated that the variations are associated with the structure of the interplanetary magnetic field which depends on interplanetary shock waves. The relative "proton" geoeffectiveness of the Sun southern hemisphere is significantly lower than of the northern hemisphere in both the 20th and the 21st cycles. Empirical distributions of standard characteristics of the SCR proton intensity profile and regression relations have been derived. They can be used to predict radiation parameters of SCR events.

[Text] During the 1967-1980 period, artificial earth satellites (AES) recorded about 170 solar cosmic radiation (SCR) flares [1-5]. Maximum intensity of protons in these events varied over a wide range: 10^{-2}-10^{4} $cm^{-2}s^{-1}av^{-1}$ for protons with energy E>10 MeV. The radiation situation in near-earth space (NES) worsened appreciably during these events, and radiation dosage under a shield of 1.5 cm^{-2} aluminum ranged from several tens of billions (background of galactic cosmic radiation--GCR) to hundreds of rad [6].

Method

Analysis of 120 SCR events in the 20th cycle of solar activity and 50 in the 21st cycle revealed that they lasted an average of 30-50 h. However, there were about 25 events in the 20th cycle and 18 in the 21st that were longer, in which several maximums of intensity were observed. The time profiles of these events were characterized by a complex structure.

Identification of the flares--sources of SCR protons--is one of the most difficult tasks in radiation cosmophysics. The generally recognized criteria

of relationship of SCR events near earth to flares on the sun are: anisotropia and time of arrival of high-energy protons to earth, shape of SCR intensity profile [1-5, 7, 8], parameters of electromagnetic radiation associated with the flare [1-4, 7-14].

One can obtain an additional and rather reliable criterion for the task of separating complex SCR profiles by using the intrinsic behavior of the hardness parameter γ of the proton spectrum as a function of time during a given SCR event. As shown by analysis, at the moment of arrival of SCR flux, in the vast majority of instances γ has a value of 0.4-0.8, and this is followed by rapid increase in this parameter to a value of γ_M at maximum intensity (the mean value of which for the cycle is 2.0), then slow 5-10% rise during the rest of the event. This is attributable to the fact that high-energy protons reach earth fastest [7, 8]. The typical drastic increase of γ during the period between arrival of SCR to earth and maximum proton intensity makes it possible to distinguish the moment of appearance of protons from another flare--SCR source--during a complex event. Figure 1a illustrates this pattern by the changes in γ as a function of time during events of 4-7 August 1972.

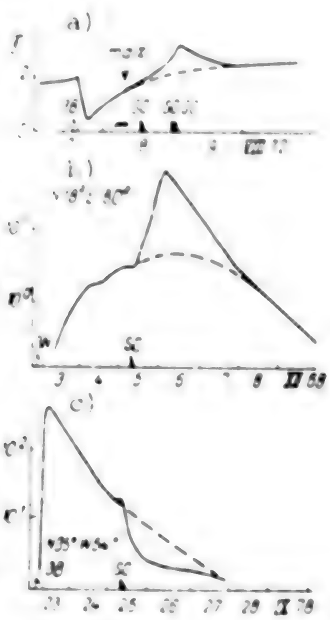

Figure 1.
Time profiles of SCR events

a) changes in hardness parameter γ of spectrum during event of 7-9 Aug 72
b, c) changes in intensity of protons with E>30 MeV (event of 3-8 Dec 68) and E>40 MeV (event of 23-26 Sep 78), respectively

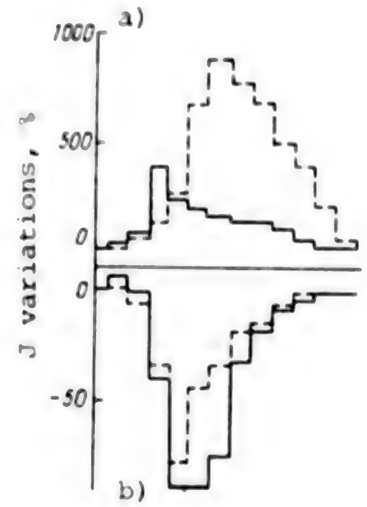

Figure 2.
Large-scale variations of time profile of intensity in SCR events
a, b) positive and negative variation

Solid line--E>10 MeV; dashes--E>60 MeV

Effect of interplanetary shock waves on time profiles of SCR events. Geoeffective interplanetary shock waves (GISW) have a substantial effect on the time profiles of SCR. In some cases, there is increase in SCR flux by a factor of 0.5-2 in relation to the normal course of intensity after passage of a wave recorded on earth according to SC; in other cases there is appreciable decrease in flux, by no more than a factor of 10^1.

As a rule, increase in flux caused by GISW occurs during the period of maximum decline of intensity, and it takes on the shape of a second maximum which could lead to identification of a false source. Such increase occurs during development of a geomagnetic storm with abrupt onset, as a result of which there is decrease in planetary hardness of geomagnetic cut-off, which worsens appreciably the radiation situation in orbits within earth's magnetosphere.

Short-term variations in intensity of SCR protons with energy of less than 1 MeV are related to the process of their acceleration on the shock-wave front.

Among the SCR events we examined, there were 72 in the 20th cycle and 25 in the 21st that were associated with variations of intensity of protons with $E>10$ MeV, when at least one SC was recorded: a) in 49 cases (33 and 16 in these cycles, respectively) there was increase in flux; b) in 10 cases (8 and 2, respectively) decrease in intensity; c) in 8 cases (6 and 2) a drastic irregularity of profile; d) in 30 cases (25 and 5) SC was recorded when proton flux was close to background and it was impossible to identify profile variations. Analysis of the heliolongitude of sources of 97 selected events revealed that 95% of the class (a) events had a flare at heliolongitude in the range of 35°W-90°E; for events of class (b) it was in the range of 35-120°W, for class (c) 30-60°W and for (d) 90°W-80°E. Hence, with flares east of heliolongitude λ_0 connected by a magnetic line of force of the interplanetary magnetic field to earth ($\lambda_0 \approx 40$-60°W), the SCR proton profile showed only positive variations of intensity, whereas with flares west of λ_0, only negative variations. Figure 1b and 1c shows, for the purpose of illustration, typical events in the 20th and 21st cycles with both types of variations. Using the method of superposed epochs, for class (a) and (b) events we obtained changes in time of positive (Figure 2a) and negative (Figure 2b) relative variations in intensity of protons with $E>10$ (solid line) and $E>60$ MeV (dash line) caused by GISW, as compared to interpolation profiles that were not exposed to GISW. We took the moment of recording SC as zero time. Figure 2 shows that relative positive variation reaches ≈400% for protons with $E>10$ MeV and ≈900% for those with $E>60$ MeV, whereas negative variation constitutes only ≈90% for $E>10$ MeV and ≈80% for $E>60$ MeV.

Let us note that the average duration of the profile variations in question constituted 40-60 h. Figure 2 shows that the effect of the shock wave on the profile is manifested 5-10 h earlier than the SC is recorded, and in both instances the variations were positive, the relative changes being almost 3 times greater for protons with lower energy. This finding can be interpreted as being the result of predominant acceleration of low-energy protons on the shock wave front. The main variations present different signs and can be well-explained by shifting of the observation point (in our cases, the AES) on the force lines of the interplanetary magnetic field that are closer to the line on which particle injection occurred (positive variations for "eastern" flares), or increased distance from observation point to force line exiting from flare--λ_F (negative variations of profile for "western" flares). This is attributable to rectification of force lines of the interplanetary magnetic field, the slope of which diminishes with increase in velocity of solar wind beyond the shock wave front. The latter leads to increase or decrease in angular distance Θ (Θ--angle between rectified force lines exiting from the flare, λ_F and λ_0, where $\Theta = \lambda_0 - \lambda_F$), which must be overcome by protons in order to reach the observation point. Such interpretation is consistent with models

of SCR proton transfer, which take into consideration diffusion across the field [7, 8]. For example, a solar wind with higher velocity was recorded beyond the shock wave front for 1-3 days, and variations in proton intensity have virtually the same duration. According to data in [7, 8], 20-50° changes in θ caused by a 160-350 km/s increase in velocity of solar wind leads to 3-6-fold change with θ≈80-100° and 1.3-2-fold change with θ≈30-50°, which also agrees satisfactorily with the results illustrated in Figure 2.

In accordance with the foregoing, we analyzed complex SCR events in 1967-1980 and in virtually all cases defined the source of SCR. This enabled us to build a rather homogeneous (~180 events) series containing the following data: characteristics of flares--SCR sources, time of proton injection, time characteristics of intensity profiles of SCR events, parameters of spectra at maximum intensity γ_M and I_{M1}($E>1$ MeV) $cm^{-2}s^{-1}av^{-1}$ and as a whole for the event γ and J_0 ($E>1$ MeV) $cm^{-2}av^{-1}$, superficial doses of radiation under shielding consisting of 1.5 and 3.0 g/cm^2 aluminum (physical and biological) calculated according to data in [11], presence of GISW during the SCR event and type of variation of time profile.

Results and Discussion

Table 1 lists the mean values of hardness parameter of proton spectrum for three heliolongitude intervals of flares--sources in the northern and southern hemispheres of the sun. They are indicative of the significant influence of the interplanetary environment on proton spectrum and are consistent with theoretical conclusions [7, 8].

Table 1.
Mean spectrum hardness parameter γ in 20th cycle of solar activity

		[illegible]	[illegible]	[illegible]	90 W– 90 [illegible]
γ_M	N	1.4	2.3	2.0	1.9 2.0
	S	1.9	2.5	~2.0	2.2
γ	N	1.6	2.4	~2.0	2
	S	2.1	2.7	~2.1	2.4 2.1

According to the data in Table 1, the spectrum of SCR protons softens as the heliolongitude of the flare λ_F moves farther from λ_0, and the spectra of protons from flares in the northern hemisphere were harder. Heliolongitude softening is the result of the process of propagation of SCR in the interplanetary environment (difference between coefficients of diffusion along and across the interplanetary magnetic field), while heliolatitude softening cannot be explained from this vantage point, and we should merely expound the hypothesis that the solar magnetosphere affects propagation of SCR. To illustrate this assumption, Figure 3 shows the results of analysis of changes in γ during events of the 20th cycle, namely the frequency of appearance of spectra with given γ for flares from the northern (solid line) and southern (dash line) hemispheres.

These distributions not only confirm the fact that the spectra from flares in the southern hemisphere are softer, but that there is relatively low proton geoeffectiveness of the southern hemisphere of the sun.

Figure 3.
Empirical distributions of parameter of spectrum hardness in SCR events
Solid line--from flares in northern hemisphere of the sun; dash line--from flares in southern hemisphere

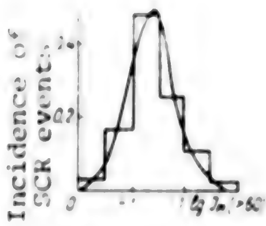

Figure 4.
Empirical distribution of maximum proton intensity in SCR event

Analogous results were obtained for SCR events in the 21st cycle. For example, the source of 40 out of the 54 events in 1976-1980 was in the northern hemisphere of the sun and only the source of 14 was in the southern one.

Empirical distributions of "fluences" [?] $J(E>E_0)$ and maximum intensity of protons--$I_M(E>E_0)$, as well as their approximations to logarithmically normal distribution for energies of >10, 30 and 60 MeV in longitude intervals of λ = 90°E-90°W and λ = 0-90°W were obtained on the basis of data about SCR events in the 20th and 21st cycles of solar activity. The parameters of approximating distributions are listed in Table 2 (designations are the same as those used in [15]). As an illustration, Figure 4 shows empirical distribution $I_M(E>10)$ for λ = 0-90°W and its approximation.

Table 2. Parameters of approximating distributions for J and I_M

Param. ξ	λ	E_0	σ	m	$M_\xi^1 \pm s/\sqrt{n-1}$	D_ξ
	90°E–90 W	10	2,1	14	$1{,}1\ 10^7 \pm 8\ 10^6$	$9{,}7\ 10^{15}$
		30	2,05	11	$5{,}4\ 10^5 \pm 3\ 10^5$	$2{,}4\ 10^{13}$
$J\ (E>E_0)$		60	2,0	9,5	$1{,}0\ 10^5 \pm 8\ 10^4$	$5{,}2\ 10^{11}$
		10	2,1	13	$4{,}0\ 10^6 \pm 3\ 10^6$	$1{,}3\ 10^{15}$
	0–90°W	30	2,0	11	$4{,}4\ 10^5 \pm 3\ 10^5$	$1{,}0\ 10^{13}$
		60	2,0	10	$1{,}6\ 10^5 \pm 1\ 10^5$	$1{,}4\ 10^{12}$
		10	2,0	2,8	$1{,}2\ 10^2 \pm 7\ 10^1$	$7{,}9\ 10^5$
	90°E–90°W	30	2,0	1,0	$2{,}0\ 10^1 \pm 1\ 10^1$	$2{,}2\ 10^4$
		60	1,9	−0,36	$4{,}2\ 10^0 \pm 2{,}8\ 10^0$	$6{,}5\ 10^2$
$I\ (E>E_0)$	0–90°W	10	2,1	2,3	$9,\ 10^1 \pm 8\ 10^1$	$6{,}7\ 10^5$
		30	2,0	0,9	$1{,}8\ 10^1 \pm 1\ 10^1$	$1{,}8\ 10^4$
		60	1,9	−0,69	$3,\ 10^0 \pm 2\ 10^0$	$3{,}3\ 10^2$

We then obtained empirical distributions for the time when the SCR event started (t_H), time of maximum intensity (t_M) and decline (t_C). We used gamma distributions as approximating ones. Table 3 lists the parameters of these distributions (designations are the same as in [15]).

Table 3.
Parameters of approximating distributions for t_H, t_M, t_C

Param. t	α	λ	$M_t \pm \sigma/\sqrt{n-1}$	D_t
t_H (E>60, 30 & 10)	1	0,50	2,0±0,3	4.0
t_M (E>60)	2	0,36	5,5±0,5	15
t_M (E>30)	2	0,30	6,7±0,6	22
t_M (E>10)	2	0,23	8,8±0,8	39
t_C (E>60)	1	0,025	40±5	1600
t_C (E>30)	1	0,020	50±6	2500
t_C (E>10)	1	0,015	70±9	4500

Table 4.
Coefficients of regression

Param. t	$a \pm \Delta a$	$b \pm \Delta b$	$R \pm \Delta R$
t_M ($\bar{\lambda}_0$)	6,2±2	4,5±3	0,83±0,03
t_M (λ_0)	5,5±2	5,0±3	0,93±0,02
t_H (λ_0)	1,3±0,5	0,7±0,5	0,80±0,08

All of the approximating distributions for the considered characteristics of SCR event profiles conform to empirical distributions according to Kolmogorov's criterion at a significance level of 0.9 [15]. On the basis of data in Tables 2 and 3, we obtained the statistical mean profiles of SCR proton flux and relative changes in fluence during an event. From these data we found that a 20% fluence is obtained 6.5, 8.5 and 11 h from the time of generation of protons with E 60, 30 and 10 MeV in a statistically mean SCR event. If such a fluence level is taken as the threshold, the above time intervals would be at the top range of fitness ["timeliness"] of extrapolation methods for predicting the radiation situation in near-earth space.

Deviations of the time profile of SCR proton intensity in this event from the statistical mean could be related to the energy of the flare-source, its heliocoordinates and characteristics of the interplanetary environment. As shown by analysis of 250 time profiles of proton intensity, which were calculated using the model described in [8], we should include primarily the force of the flare and heliolongitude--λ_F among the most important parameters that have a substantial effect on standard characteristics t_M, I_M and J of the profile. According to [8], there is a link between t_M and λ_F:

$$t_M = a\theta^2 + b, \tag{1}$$

where a = 4.3±0.4 and b = 6.0±0.5.

Analogous empirical relationships were obtained for 76 actual SCR time profiles for protons with 30<E<60 MeV. Table 4 lists the coefficients of empirical relationships of the (1) type for $\overline{\lambda_0}$ = 60°W and λ_0 value calculated from data about velocity of solar wind in the interval from the flare to maximum intensity [16].

The coincidence of coefficients in (1) within the margin of error and the rather high coefficients of correlation are indicative of adequacy of the model in [8] to some extent for use in forecasting time profiles of SCR. With this in mind, we obtained the following types of statistical correlations between θ and I_M, I:

$$I_M(E > E_0, \lambda_F) = I_M(E > E_0, \bar{\lambda}_0) \times \times \exp\{-c|\bar{\lambda}_0 \pm \lambda_F|\}, \tag{2a}$$

$$J(E > E_0, \lambda_F) = J(E > E_0, \bar{\lambda}_0) \times \times \exp\{-d|\bar{\lambda}_0 \pm \lambda_F|\}. \tag{2b}$$

where c = 0.020, d = 0.018 for E>30 MeV and c = 0.030, d = 0.025 for E>60 MeV. The coefficients of correlation for equations (2) are in the range of 0.90-95, while the functions themselves agree satisfactorily with [17].

Thus, empirical distributions of the main radiation and dynamic characteristics of SCR events, together with statistical functions (1) and (2) are the methodological basis for climatological forecasts of the radiation situation, which make it possible to obtain standard characteristics of the time profile of SCR proton intensity when only one base parameter is available--heliolongitude of the flare--λ_F. Consideration of the force of the flare of a concrete SCR event could be made by means of electromagnetic radiation that is generated in the flare [10, 12-14].

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SOME DISTINCTIONS REFERABLE TO AMINO ACID LEVELS IN BLOOD OF COSMONAUTS WHO PARTICIPATED IN 185-DAY FLIGHT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 27 Oct 82) pp 23-29

[Article by I. G. Popov and A. A. Latskevich]

[English abstract from source] This paper presents data on the content of 17 free amino acids in plasma of the crewmembers before and after the Salyut-6 185-day flight. Measurements were performed by an automatic amino acid analyzer. Postflight the content of most amino acids was lower than preflight. It is concluded that, in order to increase the amino acid supply, preflight diets should be supplemented with all amino acids, particularly, methionine, threonine, isoleucine, cystine, arginine, alanine, histidine, and postflight diets with all amino acids.

[Text] It is of great interest to study the dynamics of blood plasma free amino acid levels in cosmonauts as related to flights of different duration, since this would make it possible to offer a deeper physiological and hygienic assessment of the state of protein and amino acid metabolism at different stages of flights, as well as to define the cosmonauts' requirements as to essential and nonessential amino acids. The results of such studies provide objective material for subsequent refinement of inflight food allowances. Such information is also of some value to assessment of the functional state of the liver, kidneys and other physiological systems of the body.

In spite of the existence of a number of data on levels of free amino acid in blood plasma of cosmonauts before and after flights [1-6], there are still many unanswered questions concerning the dynamics of blood plasma amino acid levels as related to flight conditions, diet, individual metabolic characteristics and (especially) flight duration.

We report here the results of assaying 17 free amino acids in blood plasma of the crew of Salyut-6 orbital station before and after a 185-day flight; analysis was made of the distinctions of amino acid status of blood plasma in comparison to data obtained during other flights, as well as of the possible factors affecting amino acid concentration in plasma.

Methods

Blood plasma free amino acids were assayed in the cosmonauts during the period of preflight training in the course of a regular [scheduled] clinical and physiological examination (CPE), and on the 1st and 7th days after the 185-day flight. We determined the levels of 17 free amino acids in samples of venous blood plasma taken and processed by standard methods, using a Hitachi (model KLA-3V) automatic amino acid analyzer [3, 5-9]. The findings were compared to data of other authors [1, 2, 10-15] and results of tests conducted during missions aboard Salyut-5 and Salyut-6 stations [3-6].

Results and Discussion

Table 1 lists data on blood plasma free amino acid levels in the commander (CDR) and flight engineer (FLE) of Salyut-6 orbital station, before and after 185-day flight.

During the period of the preflight work-up, the concentration of most of the blood plasma amino acids tested were in the range of the "approximate [or tentative] data for adults," which are cited by I. S. Balakhovskiy in BME [Great Medical Encyclopedia] [10]. Only the concentration of aspartic acid was somewhat lower in both cosmonauts and that of cystine in the CDR was lower than the bottom range of the "approximate data."

Preflight tests on other cosmonauts also revealed lower levels than the bottom range of the standard given in BME for aspartic acid [3-6]. A. S. Ushakov and T. F. Vlasova [1, 2] cite even lower concentrations of aspartic acid (0.11 ± 0.01 mg% and even 0.07 ± 0.05 mg%). Several other authors cited as the standard 0.01-0.07 mg% [11, 12], from traces to 0.72 mg% [13], 0.30 ± 0.02 mg% [14] and 0.03 mg% [15] (true, these figures were based on testing representatives of other occupational groups). Some of the cited figures are close to ours. All this leads us to consider that the bottom of the normal range cited in BME is somewhat high. Apparently, the preflight concentration of aspartic acid in our cosmonauts was in the range of physiological fluctuations for healthy adults.

Plasma cystine content was 0.14 mg% lower in the CDR preflight than the bottom of the range in the "approximate data" in BME. If we consider as the norm the values recommended by other authors (for example, Muller [13]), the concentrations of cystine we found should also be considered somewhat low. Lower concentrations of cystine than given in BME were also demonstrated in the crews of Salyut-5 and Salyut-6 [10]. On the basis of examination of many cosmonauts, A. S. Ushakov and T. F. Vlasova suggested that a lower concentration of cystine than cited in BME be taken as the average: 0.73 ± 0.04 mg% and 0.91 ± 0.10 mg% [2]. Perhaps, the relatively lower concentrations of cystine that we demonstrated, as well as those cited by A. S. Ushakov and T. F. Vlasova, are attributable to causes in common for all cosmonauts: specifics of vital functions, diet, age. Interestingly, V. Ye. Artamonova et al. [14], who screened medical students, demonstrated cystine concentrations that were close to our findings (0.74 ± 0.06 mg%) and lower than cited by the above-mentioned authors [10, 11, 13].

Table 1. Blood plasma free amino acid levels (mg%) in crew of Salyut-6 scientific research station before and after 185-day flight

Amino acid	CDE					PLE					Approximate data on blood plasma amino acid levels according to I. S. Balakhovskiy [10]		Levels in blood plasma for adults according to Muller [13]	
	preflight	1st postflight day	changes during flight		7th postflight day	preflight	1st postflight day	changes during flight		7th postflight day	range	mean	range	mean
			mg%	%				mg%	%					
Essential amino acids														
Lysine	3,25	2,05	−1,20	−36,03	2,43	3,19	1,98	−1,21	−37,94	2,04	1,0−4,0	2.5	2,1[illegible]−3,09	2,54
Threonine	1,19	0,97	−0,22	−18,49	1,08	1,29	0,85	−0,44	−34,11	1,08	1,0−3,0	2,0	1,22−3,93	1,94
Valine	1,88	1,87	−0,01	−0,54	2,72	2,64	2,04	−0,60	−22,73	1,79	1,5−3,0	2,25	1,36−2,66	1,99
Methionine	0,31	0,31	0	0	0,34	0,31	0,19	−0,12	−38,71	0,27	0,3−0,7	0,5	0,23−0,39	0,32
Leucine	1,54	1,18	−0,36	−23,38	1,50	1,77	1,07	−0,70	−39,55	1,15	1,0−3,0	2,0	0,93−1,78	1,32
Isoleucine	0,73	0,66	−0,07	−9,59	0,91	0,74	0,49	−0,25	−33,79	0,72	0,5−1,0	0,75	0,46−1,15	0,71
Phenylalanine	0,85	0,71	−0,14	−16,48	0,73	1,03	0,57	−0,56	−44,67	1,15	0,5−2,0	1,25	0,63−1,92	0,95
Nonessential amino acids														
Cystine	0,86	0,26	−0,60	−69,77	0,74	1,03	0,44	−0,59	−57,29	0,63	1,0−3,0	2,0	1,15−3,37	1,77
Tyrosine	1,04	0,65	−0,39	−37,50	0,73	1,01	0,83	−0,18	−17,83	0,80	0,6−2,0	1,3	0,65−1,13	0,91
Alanine	2,54	1,66	−0,88	−34,65	2,35	3,99	2,60	−1,30	−34,86	2,86	2,0−4,0	3,0	2,22−4,47	3,07
Arginine	1,68	1,16	−0,52	−30,96	1,26	1,44	0,88	−0,56	−38,89	0,88	1,0−3,0	2,0	0,86−2,63	1,43
Aspartic acid	0,38	0,22	−0,16	−42,11	0,29	0,59	0,27	−0,32	−54,24	0,30	2,0−5,0	3,5	Следы−0,72	0,22
Histidine	1,23	0,58	−0,65	−52,85	0,66	0,97	0,89	−0,08	−08,25	0,80	0,8−2,0	1,4	0,97−1,45	1,24
Glycine	1,40	1,12	−0,28	−20,0	1,29	1,57	1,06	−0,51	−32,49	1,17	1,0−4,0	2,5	1,08−3,66	1,74
Glutamic acid	2,35	2,18	−0,17	−7,24	2,63	2,16	1,31	−0,85	−39,36	1,34	0,7−4,0	2,35	0,25−1,73	0,86
Proline	1,71	1,09	−0,62	−36,26	1,67	2,70	0,56	−2,14	−79,26	1,60	0,5−3,0	1,75	1,28−5,14	2,71
Serine	1,42	0,70	−0,72	−50,71	0,87	1,40	0,63	−0,77	−55,00	0,91	1,0−2,0	1,5	0,68−2,04	1,18

Cystine metabolism is closely linked with methionine metabolism. When there is a shortage of cystine in the body (for example, due to shortage in the food allowance) it is synthesized from methionine. Additional outlay of methionine for synthesis of cystine should lead to increased outlay and decreased methionine content in plasma provided, of course, if the diet does not properly cover this additional outlay of methionine. The preflight concentration of blood plasma methionine was found to be the same in both cosmonauts--0.31 mg%, i.e., it conformed to the lower range of the approximate norm cited in BME [10], but somewhat lower than the bottom limit according to N. V. Semenov [11] and 0.08 mg% higher than the bottom limit according to Muller [13]. A. S. Ushakov and T. F. Vlasova cite even lower figures than ours for the CDR and FLE of Salyut-6--0.26±0.01 mg% [1]. However, in another article they refer to higher concentrations--0.54±0.04 mg% [2]. From this we can conclude that the blood plasma methionine content was relatively low in both cosmonauts (at the bottom of the physiological range or even lower). This circumstance could be attributable to the relatively low intake of cystine and methionine with the food allowance. Analogous causes of low cystine and methionine levels in blood plasma of other cosmonauts in the preflight period were demonstrated previously in an analysis of the amino acid status of the crews of Salyut-5 [3-5] and Salyut-6 [6]. Moreover, the body's use of methionine and cystine could have been somewhat increased due to the intensive preflight training, in particular, physical conditioning.

As for the levels of other blood plasma amino acids, we can note the following. In the CDR the concentration of lysine was above mean values, and it was close to the top of the normal range cited in BME [10]. The concentrations of isoleucine, glutamic acid and proline conformed to mean values; valine, leucine, phenylalanine, tyrosine, alanine, arginine, histidine and serine levels were somewhat lower than mean values, while threonine and glycine were close to the bottom of the approximate range given in BME [10]. On the whole, in the CDR only 2 out of the 10 nonessential amino acids were on an average level or exceeded it. The concentrations of four amino acids (threonine, methionine, cystine and glycine) were relatively low and even somewhat lower than the approximate data in BME [10]. In the FLE, the concentrations in plasma of lysine, valine, alanine and proline were above the mean normal values cited in BME [10], and were close to the top of the range. In this cosmonaut, the isoleucine concentration corresponded to the average; leucine, phenylalanine, tyrosine, arginine, glutamic acid and serine levels were somewhat higher than the mean values, while threonine, histidine and glycine were close to the bottom range of approximate data cited in BME [10]. Consequently, in the FLE, only 3 out of the 7 essential and 2 out of the 10 nonessential amino acids were at the average level or above it. The concentrations of the rest of the amino acids were below the means, and five amino acids (threonine, methionine, cystine, glycine and histidine) presented relatively low levels.

Thus, in the preflight period blood plasma levels of most amino acids were somewhat lower than the mean in both cosmonauts, as compared to the approximate data in BME [10], and the concentrations of four amino acids (threonine, methionine, cystine and glycine) were low, and relatively lower than of other amino acids. This uniqueness of the amino acid status could be attributable to both the chemical composition of the diet and increased utilization of amino acids during the period of intensive preflight training.

Table 2. Overall parameters of levels of 17 amino acids (mg%) in blood plasma of Salyut-6 crew before and after 185-day flight

INDICATORS OF AMINO ACID STATUS	CDR					FLE					APPROXIMATE DATA FOR ADULTS ACCORDING TO I. S. BALAKHOVSKIY [10]		LEVELS IN BLOOD PLASMA FOR ADULTS ACCORDING TO MULLER [13]	
	PREFLIGHT	FIRST POSTFLIGHT DAY	CHANGES DURING FLIGHT		SEVENTH POSTFLIGHT DAY	PREFLIGHT	FIRST POSTFLIGHT DAY	CHANGES DURING FLIGHT		SEVENTH POSTFLIGHT DAY	PHYSIOL. FLUCTUAT.	MEAN	PHYSIOL. FLUCTUAT.	MEAN
			MG%	%				MG%	%					
TOTAL AMINO ACIDS	24,36	17,37	−6,99	−28,7	22,2	27,83	16,66	−11,17	−40,14	19,49	16,4–48,7	32,55	16,08–40,25	28.[illegible]
TOTAL ESSENT. AMINO ACIDS (E)	9,75	7,75	−2,00	−20,52	9,71	10,97	7,19	−3,78	−34,46	8,20	5,8–16,7	11,25	6,94–13,92	10.43
TOTAL NON-ESSENT. (N)	14,61	9,62	−4,99	−34,16	12,49	16,86	9,47	−7,39	−43,84	11,29	10,6–32,0	21,3	9,14–26,33	[illegible]
E/N RATIO	0,66	0,80	+0,11	—	0,77	0,65	0,76	+0,11	—	0,73	0,54–0,52	0,53	0,75–0,52	[illegible]

Note: The overall indicators were calculated on the basis of the data of I. S. Balakhovskiy [10] and Muller [13] concerning blood plasma levels of the amino acids listed in Table 1.

According to the data in Table 2, overall essential amino acid content was lower in both cosmonauts before the flight than the sum obtained by processing the approximate data in BME [10]. The overall amino acid content was 8.19 mg% lower for the CDR and 4.72 mg% lower for the FLE than when calculated from the mean values referable to the approximate data in BME (see Tables 1 and 2). Total essential and, particularly, nonessential amino acid levels were also lower in both cosmonauts than this indicator when calculated according to the approximate data cited in BME [10]. The ratio of essential to nonessential amino acids was, on the contrary, higher. This is attributable to the fact that, as compared to the approximate data in BME, the sum of nonessential amino acids was more diminished than that of essential amino acids.

The test made on the 1st day after the 185-day flight, both cosmonauts presented a decline in concentration of virtually all blood plasma amino acids, as compared to preflight status. In the CDR, of the essential amino acids, maximum decline was referable to lysine (by 36.03%), leucine (by 23.38%), threonine (by 18.49%) and phenylalanine (by 16.48%). Isoleucine showed a less significant decline (by 9.59%), whereas methionine and valine demonstrated virtually no change. Among the nonessential amino acids, the greatest decline was referable to cystine (by 69.74%), histidine (by 52.85%), serine (by 50.71%) and aspartic acid (by 42.11%). There was less marked decrease in concentrations of tyrosine, proline, alanine and arginine (by 30-40%). Glycine and glutamic acid concentrations decreased even less (by 20 and 7.24%, respectively). Overall amino acids and total essential amino acids of blood plasma dropped to the bottom of the range of this parameters calculated on the basis of the approximate data in BME, whereas

total nonessential amino acids decreased to even less than the bottom range. It is not surprising that the ratio of essential to nonessential amino acids began to exceed this parameter in the CDR, as compared to the one cited in BME for approximate data.

In spite of the decrease in concentrations of all amino acids in the FLE immediately after the flight, the plasma levels of lysine, valine, leucine, phenylalanine, tyrosine, alanine, histidine, glycine, glutamic acid, proline and serine remained in the range of approximate levels given in BME [10]. However, the concentration of threonine, methionine, isoleucine, cystine and arginine dropped and was below the bottom range of the above-mentioned norm. The concentration of aspartic acid, which was lower preflight than indicated in the approximate data in BME, dropped even more after the flight. Overall amino acids and total essential amino acids in blood plasma decreased in the FLE, as in the CDR, to the bottom range for these parameters when calculated from the approximate data in BME [10], while the sum of nonessential amino acids dropped below the bottom of the range of normal physiological fluctuations. As in the CDR, the essential to nonessential amino acid ratio increased even more and exceeded this indicator when calculated from the approximate data in BME [10].

Thus, against the background of general and appreciable decrease in concentration of most amino acids in both cosmonauts, in the course of the flight there was maximum decline of lysine level (by 36% for the CDR and 38% for the FLE), leucine (by 23 and 39%), threonine (by 18 and 34%), phenylalanine (by 16 and 45%), cystine (by 70 and 57%), tyrosine (by 37 and 18%), serine (by 51 and 55%), aspartic acid (by 42 and 54%), proline (by 36 and 79%), alanine (by 35 and 35%), arginine (by 31 and 39%) and glycine (by 20 and 32%). The threonine and cystine levels in blood plasma of both cosmonauts, while alanine and histidine levels in the CDR, methionine, isoleucine and arginine levels in the FLE postflight were below the bottom of the range of approximate levels for adults cited in BME [10]. Before the flight, only cystine level was lower in the CDR than the above norm.

The demonstrated changes in amino acid status of the cosmonauts could be attributable to various causes, for example they could be nutritional due to inadequate intake of amino acids with the food allowance. Poorer absorption in the gastrointestinal tract, changes in protein and amino acid metabolism under the influence of the unusual spaceflight conditions, including the increased amino acid requirements of the body, could also be significant. Intensification of anabolic processes associated with outlay of amino acids during descent and landing, as a reaction to returning to earth's gravity and an increased load on the cosmonauts' muscular system already in the first postflight hours could also have had some effect. In such a case, the demonstrated changes in amino acid status developed, at least in part, already on earth, rather than during the flight. It should be borne in mind that the changes occuring in the body and metabolism during the flight could create the necessary conditions for rapid development of the demonstrated changes in amino acid metabolism during descent from orbit immediately after landing.

Tables 1 and 2 also list the results of assaying blood plasma free amino acid concentrations on the 7th postflight day. According to the data listed in these

tables, blood plasma levels of all essential and nonessential amino acids rose by the 7th postflight day in the CDR, as compared to their status on the 1st postlanding day. However, only the concentrations of valine, methionine, leucine, isoleucine, glutamic acid and proline reached or somewhat exceeded the levels present preflight during the physical work-up. There was an increase in total essential and nonessential amino acids; however, these parameters were still below base levels on the 7th day. Consequently, during this period there was an appreciable increase in supply of free amino acids, as compared to the 1st postflight day, but it did not yet reach the preflight level. In the FLE, on the 7th postflight day the concentrations of 11 out of 17 amino acids also increased, as compared to the status on the 1st postflight day. At the same time, the concentrations of two amino acids (valine and histidine) were even lower, while four others (tyrosine, arginine, aspartic and glutamic acids) remained at virtually the postflight level. Overall amino acids, as well as sums of essential and nonessential amino acids were above the postflight level on the 7th day. The essential to nonessential amino acid ratio dropped in the FLE, as in the CDR, and came close to the base value. By the 7th day of the postflight period, in the FLE the concentrations of only 3 out of 17 amino acids (methionine, isoleucine and histidine) almost reached the base preflight levels but did not exceed them. In this respect, there was apparently slower restoration of the base amino acid status in the FLE than the CDR.

The data submitted here enable us to derive several conclusions and offer some suggestions.

In the preflight training period, it would be desirable to increase somewhat the methionine and cystine, as well as threonine and glycine, content in the cosmonauts' diet.

Evidently, one should increase the amounts of all amino acids in the daily food allowance intended for long-term flights, and first of all this applies to methionine, threonine, isoleucine, cystine, arginine, alanine and histidine, the levels of which in blood plasma were lower postflight or at the bottom of the range of physiological fluctuations cited in the approximate figures for adults [10]. When organizing rehabilitation nutrition for cosmonauts for the first few postflight days, taking into consideration activation of anabolic processes, particularly in muscle tissue, it would be expedient to increase the sources of all amino acids, particularly methionine, cystine, valine, histidine, tyrosine, arginine, aspartic and glutamic acids.

It is still of great scientific and practical interest to take blood samples for assay of amino acids in the course of long-term spaceflights, and primarily in their beginning and final stages.

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MYOELECTRIC ACTIVITY OF THE RAT DUODENUM UNDER HYPOKINETIC CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 18 ... [illegible]) pp 30-32

[Article by A. N. Petrusenko]

[Text] At the present time there has been convincing demonstration of changes that occur in the human and animal digestive tract under the effect of weightlessness and hypokinesia [1, 2].

There are appreciable changes in peristaltic and evacuating functions of the stomach and small intestine [3].

A decrease in propulsive and contractile function of the intestine was demonstrated in experiments on animals using roentgenological and balloonographic techniques [4, 5], with restricted motor activity (RMA).

However, these methods, which reflect only the overall ultimate effect of altered peristalsis in the small intestine, do not disclose the intimate electrophysiological mechanisms of functional disorders in the muscular layer of the intestine.

Our objective was to study the bioelectrical activity of the duodenum, which occupies a prominent place in coordination of function of the hepato- and pancreato-duodenal regions under RMA conditions.

Methods

The study of electrical activity of the duodenum was pursued on 8 mongrel white male rats weighing 180-200 g. The animals were put in special box-cages to create RMA [2].

Electrical activity of the duodenum was recorded using bipolar platinum electrodes implanted under the serous membrane in the duodenal wall. A Mingograph-81 instrument was used to record the tracings.

We studied the following parameters of bioelectric activity: amplitude and frequency of slow electric waves (SEW), number of spikes per group per SEW, active phase of migrating myoelectric complex, which is the bioelectrical analogue of the interdigestion periodic motor activity [6]. The active phase

of the migrating myoelectric complex consists of a group of SEW with spikes on each of them [7].

Bioelectrical activity of the duodenum was recorded in the background period, on the 4th, 7th, 15th, 30th, 60th and 90th days of RMA on both a fasting stomach and during the period of digestion. The alimentary reaction was evaluated in response to feeding the animals 2 g of pellet feed.

Results and Discussion

During RMA there were changes in amplitude of duodenal SEW.

On a fasting stomach, we observed progressive decline of amplitude of SEW of the migrating myoelectric complex starting on the 4th day of RMA, and it became reliable on the 15th day of RMA (Table 1). By the 90th day, the SEW amplitude constituted only 55% of the base value.

Table 1. Mean amplitude of SEW in active phase of migrating myoelectric complex of rat duodenum with RMA

Parameter	Base values	Day of restricted motor activity					
		4	7	15	30	60	90
M m P	538,9 54,75	429,0 63,8 >0,05	421,4 69,43 >0,05	350,0 59,6 <0,05	349,0 55,24 <0,05	329,0 48,13 <0,05	295,0 60,4 <0,05

Table 2. Mean frequency of duodenal SEW in fasting rats with RMA (cycles/min)

Parameter	Base values	Day of restricted motor activity					
		4	7	15	30	60	90
M m P	39,0 0,76	37,6 0,35 >0,05	36,7 0,34 <0,05	36,5 0,55 <0,05	35,9 0,37 <0,01	34,8 0,37 <0,01	33,9 0,27 <0,01

The frequency of SEW in the fasting duodenum diminished reliably starting on the 7th day of RMA (Table 2). By the 90th day SEW frequency was lower than its base value by 4.9 cycles/min, or 10%.

The number of spikes per train per SEW in the active phase of the migrating myoelectric complex diminished reliably from the 30th day of RMA. The presence of a direct dependence of force of smooth muscule contraction on number of spikes per SEW [8] led us to conclude that there is appreciable depression of contractile activity of the duodenum (Table 3).

Table 3. Mean number of spikes per group in one SEW of active phase of migrating myoelectric complex with RMA

Parameter	Base values	Day of restricted motor activity					
		4	7	15	30	60	90
M	5,1	4,53	4,9	4,35	3,92	4,1	4,11
m	0,41	0,27	0,48	0,26	0,2	0,32	0,2
P		>0,05	>0,05	>0,05	<0,05	<0,05	<0,05

There was considerable change in magnitude of active phase of migrating myoelectric complex: starting on the 4th day of RMA, the number of SEW with spikes was reliably diminished. By the 60th day of RMA this parameter declined even more and reached 49%.

There was insignificant change in frequency of appearance of migrating myoelectric complexes per hour during RMA.

The changes in quantitative composition of the active phase of the migrating myoelectric complex with RMA apparently reflect changes in regulation of interdigestion peristalsis by motilin-producing structures, which are controlled by cholinergic nerve elements [9].

A functional load with use of measured feed also revealed substantial changes in electrophysiological reaction of the duodenal wall with RMA.

In the background period, during feed intake, there was 73% increase in SEW amplitude, as compared to fasting level. However, already on the 4th day of RMA, there was decrease in increment of SEW amplitude during feed intake to 29%, and by the 90th day this parameter constituted only 10%.

Reactivity of the myoneural system of the duodenum, which was also manifested by decline in SEW frequency during food intake decreased by 35% by the 90th day of RMA.

During food intake, the number of spikes per SEW was reliably lower on the 30th day of RMA.

During the digestive period, 1 h after feeding, RMA elicited a decrease in SEW frequency and spike activity, as manifested by decrease in mean number of spikes per SEW. SEW amplitude did not change appreciably.

The decrease in force of contractions and their frequency, shortening of the active phase of the migrating myoelectric complex under the influence of RMA could apparently be the cause of slower passage of food through the intestine, and this had been noted previously using the roentgenological method on dogs and rats [4, 10] with RMA.

Thus, as a result of restricting motor activity of rats, there was substantial depression of motor activity of the empty duodenum starting on the 7th day:

[illegible] the decrease in amplitude of SEW of the active front of the migrating myoelectric complex, which is directly related to duration of RMA; decrease in SEW frequency, which progressed with increase in duration of RMA; diminished spike activity; decreased active phase of the migrating myoelectric complex under the influence of RMA. The functional test with measured feeding revealed a substantial decline of electrophysiological parameters of the duodenum during food intake and in the period of digestion under the effect of RMA: the food load test revealed depression of both the amplitude and frequency components of reactivity of the myoneural system of the duodenal wall; a decrease in SEW frequency and spike activity was noted in the period of digestion.

The findings warrant the conclusion that contractility of the duodenum is depressed under the influence of RMA.

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ENERGETIC REACTIONS IN RAT SKELETAL MUSCLES AFTER FLIGHT IN COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 10 Feb 82) pp 32-36

[Article by E. S. Mailyan, L. B. Buravkova and L. V. Kokoreva]

[English abstract from source] The polarographic analysis of biological oxidation in rat skeletal muscles after the 18.5-day flight revealed changes specific for the flight animals: oxidative phosphorylation uncoupling, distinct inertness of energy accumulation 10 hrs after recovery. Tissue respiration inhibition occurred in both flight and synchronous rats suggesting the effect of other than weightlessness factors. In the flight animals the parameters of energy metabolism returned to the prelaunch level within a longer (29 days) time than in the synchronous rats (6 days). Muscles of different function (predominance of fast or slow fibers) showed similar responses of energy metabolism to weightlessness, i.e. inhibition of the intensity and decrease of the energy efficiency of oxidative processes.

[Text] Studies have shown that the first few postflight days are characterized by functional deficiency of skeletal muscles, impaired coordination of motor acts, diminished tonus and force of muscular contractions [1-4]. One of the causes of these disorders could be inadequate energy back-up for muscular contractile function, which could occur due to lack of adaptation of muscles that are deconditioned in flight, in particular, with regard to their metabolism and energy metabolism, to earth's gravity.

It was previously demonstrated, on animals flown aboard Cosmos-605 and Cosmos-936 biosatellites, that there was depression of respiration and accumulation of energy in muscles of the mixed type, decrease in activity of cytochromoxidase and total lactate dehydrogenase 48 and 10 h after landing [5, 6]. We submit here the results of polarographic analysis of oxidative phosphorylation in different rat muscles after termination of 18.5-day spaceflight.

Methods

In this study we used three groups of Wistar SPF rats: flight, ground-based synchronous experiment and vivarium control (6-8 animals in each group).

specimens were collected 10 h after the flight and on the 6th, 29th days of the recovery period. Tests were performed on a suspension of mitochondria, which were isolated by conventional techniques [7] from the posterior group of femoral muscles, and homogenates from the same muscle group, as well as anterior tibial and quadriceps muscles. Muscles were excized 15-20 min after decapitation, and they were preserved at low temperature using 20% glycerin and saccharose (pieces of muscles were treated and stored for 2 days at temperatures ranging from +1 to -7°C).

Oxidative and phosphorulating activity of myocytes was assessed according to rate of mitochondrial respiration in the active third and adjusted fourth metabolic states [8] to (4n) and after ADP phosphorylation (4o), and according to estimated parameters of energy function of the respiratory chain: respiratory control (RC), ADP:O coefficient, phosphorylation time (Δt) and phosphorylation rate (ADP:Δt) [9]. Homogenates were examined in two metabolic states (4n and 3).

Results and Discussion

The tracing of oxygen uptake in a suspension of mitochondria isolated from skeletal muscles showed a significant reduction of respiratory rate in flight and synchronous groups of animals, as compared to the control group (Figure 1a). There was distinct depression of respiration both before and after addition of ADP to incubation medium, oxidation with succinic and NAD-dependent α-ketoglutaric (KG) acids. Since inhibition of respiratory rate of muscles was demonstrated not only in the flight group of animals, but the synchronous one, it can be considered that depression of oxidative metabolism in this experiment was related to the effects of the set of spaceflight factors reproduced on the ground (all factors with the exception of weightlessness). However, analysis of parameters of coordination of oxidative phosphorylation revealed changes inherent in the effects of weightlessness. The latter included a decrease of coefficient ADP:O and rate of phosphorylation related to increase in phosphorylation time (Table 1). At these times, the above parameters of coordination [or integration] in the synchronous experiment showed virtually no difference from the control, unlike the flight group.

Dynamic observations thereafter (6th day of recovery period) revealed even greater depression of mitochondrial respiration in the flight group of animals (Figure 1b) and, as before, low rate of phosphorylation in spite of restoration of ADP:O coefficient (see Table 1). Conversely, in the synchronous group of animals all of the parameters studied not only recovered, but exceeded control levels; phosphorylation time diminished, which was indicative of a high level of coordination of oxidative phosphorylation. Recovery of parameters of the flight group of rats was demonstrated considerably later, on the 29th day of the readaptation period.

The above patterns were confirmed by examination of muscle homogenates. In all three muscles, depression of respiratory activity was demonstrated 10 h after landing in the flight and synchronous groups of animals (Table 2). In the flight group of rats, respiratory control was lower than in the synchronous group, which was indicative of dissociation of oxidative phosphorylation in the first hours after weightlessness. The direction of changes at later stages was

the same as demonstrated for mitochondria: on the 6th day, the flight group of animals showed depression of respiration, whereas the synchronous group, on the contrary, demonstrated complete recovery (with signs of supercompensation; Figure 2). It should be noted that, by the end of the 1st month of the postflight period, recovery of base level of tissular respiration was less complete in the quadriceps (its central head) than in the other two muscles. This could serve as confirmation of the existing view to the effect that slow oxidative (red) fibers are damaged more (whereas repair processes in them are slower) than glycolytic white fibers [10].

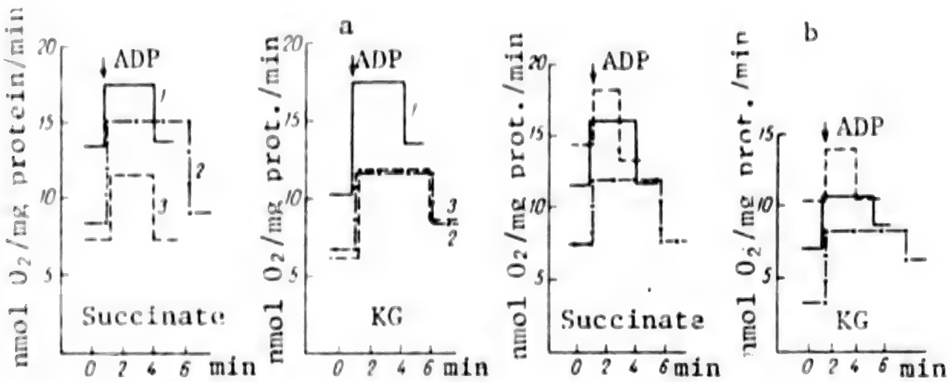

Figure 1. Rate of muscle mitochondrial respiration in different metabolic states 10 h (a) and on 6th day (b) after flight, with addition of 5 mM succinate and 7 mM KG

1-3) animals in vivarium control, flight and synchronous experiment groups

Table 1. Parameters of coordination of oxidative phosphorylation in muscle mitochondria in postflight period (M±m)

DAY OF TEST	PARAMETER	OXIDATION SUBSTRATE	GROUP OF ANIMALS: VIVARIUM CONTROL	SYNCHRONOUS EXPERIMENT	FLIGHT
FIRST	ADP:O	SUCCINATE	0,20±0,017	0,28±0,027*	0,14±0,014* ooo
		KG	0,21±0,013	0,21±0,019	0,20±0,026
	ADP:Δt	SUCCINATE	18,39±4,63	22,20±3,59	9,53±0,54oo
		KG	15,14±0,91	16,08±5,13	10,59±1,18*
	Δt (MIN)	SUCCINATE	3,40±0,51	3,12±0,62	5,32±0,27** oo
		KG	3,37±0,22	4,73±1,03	5,03±0,46*
SIXTH	ADP:O	SUCCINATE	0,19±0,027	0,24±0,028	0,20±0,027
		KG	0,23±0,015	0,25±0,026	0,26±0,038
	ADP:Δt	SUCCINATE	17,26±1,67	27,72±1,97**	11,56±1,71ooo
		KG	16,17±2,19	23,49±1,67*	9,66±1,45ooo
	Δt (MIN)	SUCCINATE	2,95±0,28	1,85±0,13***	4,74±0,71oo
		KG	3,38±0,43	2,18±0,15*	5,59±0,93* oo

Note: Statistically reliable changes in comparison to parameters for vivarium control (*--P<0.05, **--P<0.01, ***--P<0.001) and for synchronous experiment (o--P<0.05, oo--P<0.01, ooo--P<0.001).

Table 2. Respiratory rate in muscle homogenates (nmol O_2/mg protein/min) in different metabolic states and respiratory control on first post-flight day (M±m)

MUSCLE	PARAMETER	OXIDATION SUBSTRATE	ANIMAL GROUP: VIVARIUM CONTROL	ANIMAL GROUP: SYNCHRON. EXPERIMENT	ANIMAL GROUP: FLIGHT
ANTERIOR TIBIAL	V4n	SUCCINATE	14,01±3,15	9,10±3,74	8,87±1,37
		KG	11,93±1,19	5,90±2,49	8,09±1,25
	V_3	SUCCINATE	24,71±3,65	12,05±2,49*	11,70±1,45*
		KG	16,49±1,98	9,11±4,40	9,62±1,18*
	RC	SUCCINATE	2,62±0,81	2,09±0,42	1,35±0,07
		KG	1,38±0,09	1,79±0,43	1,27±0,14
QUADRICEPS	V4n	SUCCINATE	10,56±2,95	8,44±3,00	8,03±1,34
		KG	9,27±2,20	8,69±3,94	7,84±0,88
	V_3	SUCCINATE	23,21±2,03	13,87±3,90	13,31±2,08**
		KG	16,98±2,65	14,00±6,41	9,91±0,79*
	RC	SUCCINATE	3,25±0,93	1,95±0,19	1,73±0,21
		KG	2,13±0,29	1,47±0,07	1,30±0,08*
POSTERIOR FEMORAL	V4n	SUCCINATE	13,17±1,66	6,91±1,54*	6,73±0,61**
		KG	10,60±1,52	6,02±2,00	6,79±0,50*
	V_3	SUCCINATE	18,43±1,39	14,04±2,83	10,38±0,92***
		KG	14,32±1,01	10,78±3,47	8,95±0,43***
	RC	SUCCINATE	1,47±0,12	2,19±0,19**	1,59±0,13^{0}
		KG	1,47±0,18	2,06±0,36	1,33±0,08

Note: Statistically reliable changes as compared to vivarium control (*--$P<0.05$, **--$P<0.01$, ***--$P<0.001$) and synchronous experiment (^{0}--$P<0.05$).

Thus, on the basis of the submitted data it can be concluded that exposure to weightlessness for 18.5 days leads to considerable changes in muscle bioenergetics 10 h after landing: dissociation of oxidative phosphorylation and marked inertness of processes of accumulation of energy in cells of skeletal muscles. Depression of intensity of tissue respiration in this period is related to the effects of the entire set of spaceflight factors. The demonstrated slowing of reactions on the level of the respiratory chain and depression of oxygen uptake by muscles in the flight group of animals were also demonstrated on the 6th day of the recovery period, whereas in the synchronous group there was recovery at this time of tissue respiration with signs of supercompensation. In the flight group of animals, restitution of all processes studied was demonstrated on the 29th day of the readaptation period. Muscles differing in functional specialization (predominance of fast or slow fibers) present the same type of reactions of energy metabolism to weightlessness: depression of intensity and energetic efficiency of oxidative processes. Recovery of these processes can occur at different times in different muscles during the readaptation period.

The demonstrated changes in bioenergetics of muscles should be interpreted as biochemical symptoms of deconditioning of the muscular system. Impairment of energetic reactions in muscles in the postflight period, in particular of processes of accumulation of energy, could be one of the causes of diminished electromechanical cost of muscular exertion in man following a spaceflight [11].

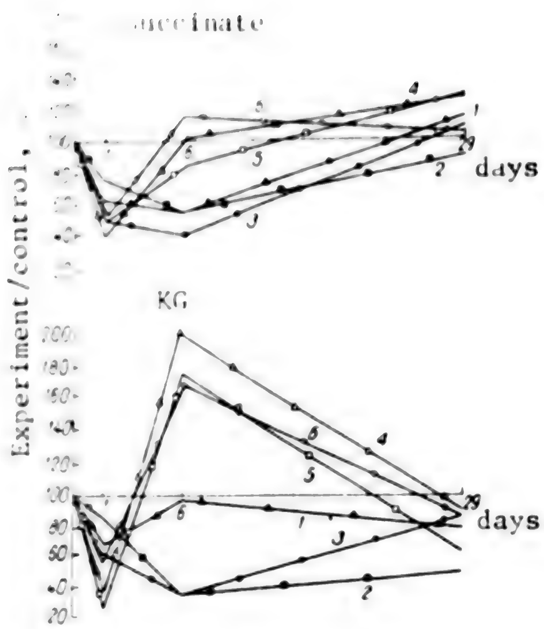

Figure 2.
Rate of respiration of homogenates of different muscles at rest (4n) in flight and synchronous experiment groups of animals (% of parameters for vivarium control group) in postflight period
1) anterior tibial muscle
2) quadriceps of thigh
3) posterior femoral muscle of flight animals
4-6) same for rats in synchronous experiment

Development of deconditioning under spaceflight conditions is justifiably related [by authors] to attenuation of afferent impulsation from proprioceptive muscles that are in a state of diminished functional activity [12]. As a result, there is blocking of the flow of information, attenuation of neurotrophic influences of the central nervous system on muscular metabolism. At the same time, apparently the absence of such an important factor in self-regulation of muscular metabolism as systematic production of ADP as a result of hydrolysis of ATP upon contraction of myofibrils plays as large a part. According to the well-known hypothesis [13], motor activity is a mandatory prerequisite for excessive anabolism, which is the basis of cell growth and synthetic recovery processes. In weightlessness, the level of anabolic processes in muscles drops and gives way to catabolic processes because of impairment of regulatory influences. Histostructural changes in subcellular structures develop in muscle cells [14], as well as atrophy, development of which is accelerated by the decrease in function of the blood-supply system--emptying of capillaries [15], due to the complex set of metabolic changes in tissues and central regulatory influence. Reduction in mass and strength of muscles is a consequence of all this. Evidently, the metabolic changes caused by the decrease in functional activity of muscles during the 18.5-day spaceflight include adaptive reduction of bioenergetic processes in skeletal muscles during the flight. However, energetic deficiency of deconditioned muscles is fully manifested after returning to earth, when the "flight" level of energy supply is not sufficient for muscle function in earth's gravity.

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GENERAL PATTERNS OF BONE ATROPHY IN THE ABSENCE OF LOAD ON SKELETON

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 12 Jan 82) pp 36-45

[Article by G. P. Stupakov, V. S. Kazeykin and A. I. Volozhin]

[English abstract from source] The rate of atrophic changes in spongy bones of the weightless man was estimated, using studies of human, dog and rat bones, as well as observations of neurological patients bed-stricken for a long time. Taking into consideration data in the literature on the bone status and mineral balance in real and simulated space flights, two models were built. The models make it possible to estimate osteoporosis of spongy bones of the axial skeleton in the absence of weight loading. One of the models--an intraspecies model for the human population--is based on the experimentally found rate of the physiological re-arrangement of various spongy bones. The other--interspecies--model is built with reference to the parameters determining the rate, i.e. bone density and metabolism. The average monthly rates of axial bone losses calculated by means of the two independent methods are essentially identical. The data obtained allow prediction of the decrease of tolerance to head-to-feet impact acceleration as a function of flight duration.

[Text] One of the main questions in the problem of the bone system and weightlessness is the rate and dynamics of development of osteoporosis in different parts of the skeleton as a function of spaceflight duration. In order to investigate this matter, a study was made of the balance of mineral salts in cosmonauts during spaceflights [1-2] and in a number of subjects under ground-based model conditions with use of bed rest [3-7]. Concurrently, an assay was made of minerals in certain skeletal bones (calcaneus, heads of the radius and ulna) that can be examined using roentgenological photodensitometry [8-11] and direct photon absorptiometry [12-14]. More recently, computer tomography has been developed for this purpose [15-17]. Evaluation of the condition of bone structures of the human spine occupies a special place in this problem, since expressly the spine could be submitted to the risk of trauma under the effect of the impact accelerations when landing a descent vehicle. There are no data on this score in the literature.

The objective of this study was to assess the severity of atrophic changes in different parts of the human skeleton on the basis of building an intraspecific (within human population) and interspecific models of bone atrophy in the absence of weight load on the bone, with consideration of physiological parameters determining the rate of resorption of bone matter.

Methods

In this study we used the results obtained previously from examination of autopsy bone material (vertebrae, calcaneus) from 120 males 20-50 years of age who expired suddenly due to causes that did not affect the condition of the bone system, as well as bone material (femur) from 64 rats flown in space for 19-22 days aboard Cosmos-615, Cosmos-782, Cosmos-936 and Cosmos-1129 artificial earth satellites and analogous specimens from 8 dogs used in 90- and 345-day experiments where support function of the femur was eliminated by means of amputation of the leg on the level of the lower third. We studied the following parameters: density of structural composition of bone according to volumetric mineral content (mineralization in grams/cm^3), mineralization of bone according to mass ratio between minerals in dry defatted bone (ash content, as percentage), concentration of chemical elements in mineral component--Ca, P, Na and K (in g, mg/100 g ash), as well as mechanical properties--tensile strength, modulus of elasticity, specific energy of elastic deformation (in kgf/cm^2). In addition, we determined dynamic strength of T_{11}-L_3 human vertebral segments with impact pulses lasting 50-70 ms. Moreover, we made use of the results of a roentgenological examination of the spine of eight neurological patients who had spent several months or years in bed. The data submitted here have been published in part previously [18-20].

We used data from literature sources concerning changes in calcium balance during bed rest in 90 subjects [21] and 9 astronauts during long-term flights [22], as well as data on mineral content of some skeletal bones [23].

Results and Discussion

Calcium balance in the absence of skeletal load was studied to determine the overall loss of calcium and equivalent loss of bone mass for a given period. We plotted overall calcium loss as a function of duration of bed rest and spaceflight (Figure 1) by integration of parameters of calcium balance taken from the literature ($\int_0^t V(t)dt$, where t is duration of factor involved, days; $V(t)$ is negative calcium balance, mg/day). Figure 1 shows that there are wide individual variations in calcium loss. Under spaceflight conditions it is virtually in the range of the confidence interval of variability for bed-rest conditions. This fact enables us to consider bed rest as a very adequate model of weightlessness with reference to the bone system.

With bed rest lasting up to 9 months, calcium loss constitutes up to 40 g, i.e., about 4% of total content in the skeleton. Such loss presents no threat to the body if it is attributable to uniform resorption of bone matter in the entire skeleton, but does present a serious danger when there

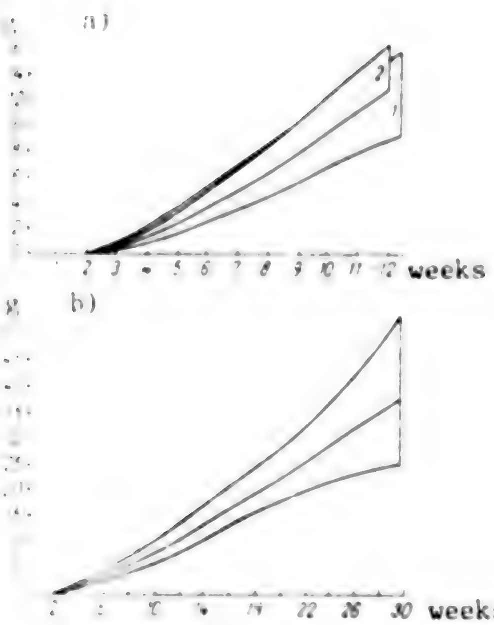

Figure 1.
Body calcium loss as a function of time (P = 0.95)
a) bed rest up to 12 weeks (1) and spaceflight (2)
b) bed rest for up to 28 weeks

is development of marked local osteoporosis. In order to elucidate this matter, we examined bone density in experiments on animals, in different parts of a bone. It has been determined that rats develop osteoporosis under the influence of weightlessness, primarily in the femoral epiphyses, i.e., regions represented by spongy substance. Loss of mineral mass in these regions reached 18-21%, and there were no overt signs of osteoporosis in the compact bone of the diaphysis [34]. In dogs, atrophy of spongy structures in the distal epimetaphyseal zone reached an average of 33% as a result of deprivation of support function of the hind leg for 3 months, and virtually failed to change thereafter. However, in the diaphyseal region, only early signs of osteoporosis developed in 3 months. These facts are consistent with data in the literature to the effect that in man also, in the case of rapidly developing pathological osteoporosis of spongy bones, atrophic changes in compact bone appear considerably later, only after the severity of atrophy (for example, in the spine) reaches a plateau, i.e., becomes stabilized [25].

Osteoporosis did not develop in bones that did not experience the load of the body's weight during spaceflights and bed rest, even in spongy bone (for example, heads of the radius and ulna) [14].

Consequently, the negative calcium balance in the absence of weight load is attributable at the early stages to resorption of spongy structures of the axial skeleton. The rate of resorption may differ in different segments.

It is known that the severity of atrophic changes in the calcaneus due to bed rest are related to excretion of hydroxyproline in urine [24], which reflects the intensity of physiological change (renewal) of bone.

Proceeding from the premise that these processes are interrelated, we assessed the severity of atrophy of spongy structures of the axial skeleton on the basis of data concerning calcium content, mass of spongy substance and rate of physiological reorganization. For this purpose, we used data cited by the experts of the International Committee for Radiation Protection [23] and the results of studies of calcium balance in 90 individuals kept on strict bed rest, 12 of whom did so for 20 weeks [21].

In this time, average calcium loss constituted 23 g. In using the primary data, the following assumptions were made: 1) in view of the absence of data

Table 1. Estimates of rate of atrophic changes in spongy structures of axial skeleton in the absence of weight load

NO	SKELETAL BONE i	MASS OF SPONGY BONE, G m_{1i}	CALCIUM MASS, G $m_{2i} = \frac{m_{1i} a}{100\%}$	RATE OF PHYSIOLOG. RENEWAL, %/YEAR V_i	MASS OF NEW CALCIUM PER YEAR, G $m_{3i} = \frac{m_{2i} V_i}{100\%}$	SHARE OF CALCIUM RENEWED PER YEAR, % $b_i = \frac{m_{3i}}{\Sigma m_{3i}} 100\%$	SHARE OF CALCIUM MASS (m_4 = 23 G) LOST IN 20 WEEKS OF BED REST, G $c_i = \frac{m_4 b_i}{100\%}$	SEVERITY OF BONE ATROPHY IN 20 WEEKS, % $d_i = \frac{c_i}{m_{2i}} 100\%$	RATE OF BONE TISSUE ATROPHY, %/MONTH V_{xi}
1	SPINE	330	38	8,3	3,15	55,2	12,7	33,5	7,3
2	PELVIC BONES	40	4,6	6,5	0,30	5,2	1,2	26,1	5,7
3	FEMUR:								
3	PROXIMAL SEGMENT	130	15	5,7	0,85	15,0	3,4	23,0	5,0
4	DISTAL SEGMENT	130	15	2,5	0,37	6,5	1,5	10,0	2,2
5	SACRUM	25	2,9	6,5	0,19	3,3	0,71	26,6	5,8
6	TIBIA	160	18,4	4,1	0,75	13,2	3,13	16,4	3,6
7	FIBULA	5	0,6	4,1	0,02	0,4	0,095	16,2	3,5
8	FOOT	15	1,7	4,1	0.07	1,2	0,283	16,9	3,7

about the amount of spongy substance in the distal and proximal epimetaphyseal regions of the femur, we considered it equal in each region; 2) we took the mean renewal parameter for analogous structures of the femur as the rate of renewal of spongy bone in the tibia, fibula and foot bones. The results of our analysis are listed in Table 1. We additionally determined by the direct method the total amount of calcium in the bodies of T_1-L_5 vertebrae of three men with average anthropometric parameters. The results conformed well with the data listed in Table 1.

As a gauge of bone atrophy, one can use the calcium loss from a specific bone since, as shown by the results of the experiments with rats and dogs described above, mineralization of bone and the proportion of calcium and phosphorus in it change insignificantly, if they change at all, and one can disregard these changes to solve our problem.

Calculation of rate of bone atrophy (V_{xi}) can be expressed in general form as follows:

where i = 1, 2, 3, ... is the bone index (shows number under which a given bone is listed in Table 1), m_4 is overall calcium loss over the period under study (in grams); V_i is rate of physiological renewal (% per year); Σm_{3i} is overall mass of replenished calcium (g/year); m_{1i} is mass of spongy bone (g); a is its calcium content (%).

The estimated rate of atrophy of pelvic and foot bones conforms well with the results of direct or instrument measurement of rate of

thinning of the structure of the iliac bone [26] and calcaneus during bed rest [6-7, 21]. Thus, in the cited works, on the basis of testing 34 samples of biopsy material from the ilium of 27 people, the rate of atrophy averaged about 6% per month, whereas in the calcaneus it ranged from 0 to 8.4% in different individuals, constituting a mean of about 4%/month.

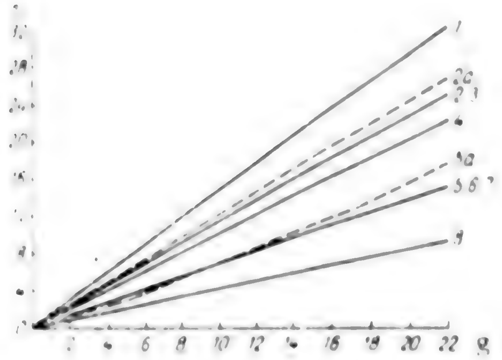

Figure 2.
Severity of atrophy of spongy bone of axial skeleton as a function of calcium loss. Solid lines--estimates, dash lines--data obtained as a result of tests
1) spine
2,3) pelvic bones, sacrum
4) proximal femoral epiphysis
5) tibia
6) fibula
7) foot bones
8) distal femoral epiphysis
2a) iliac bone [26]
5a) calcaneus [6, 21]

The rate of atrophy of different spongy bone structures during the period of active development of osteoporosis can be illustrated graphically (Figure 2). As can be seen in Figure 2, there is good agreement of estimated and experimental indicators of atrophy of structures of the calcaneus. The data in Figure 2 explain the results of a previous study of roentgenological signs of osteoporosis in the ilium and proximal epiphysis of the femur [27]. In that study, osteoporosis was diagnosed with calcium loss of 15 to 36 g and, according to the above-mentioned function, this corresponds to bone atrophy of about 18-40% in the tested regions (for average initial bone density). Such a level of bone atrophy could apparently be indeed diagnosed roentgenologically as osteoporosis of the bone in question, since overall thickness of trabecular structures is small here. For example, in the iliac bone it is 10-15 mm [23].

The high estimated rate of spinal atrophy makes it necessary to examine two interrelated questions: range of decrease in bone mass and possibility of roentgenological detection of osteoporosis.

With reference of the first question, it is expedient to assess the interspecific range of bone atrophy in order to demonstrate general biological patterns in this process. According to our data, spongy tissue in the distal epimetaphyseal region of the dog's femur deprived of support function lost an average of 35% of its mass before stabilizing, with individual fluctuations from 24 to 46%. In the analogous rat model, average loss of spongy bone constituted 34%. In man, atrophy of the ilium stabilized at the level of 35% loss in 25 weeks, with considerable individual variability [26]. In the human calcaneus, loss also varied over a wide range, exceeding 40% [21], although there is no proof in the literature that this figure characterizes the range of atrophy of this bone.

Since the calcaneus, unlike other bones of the axial skeleton, performs the role of a powerful shock absorber [28] during man's normal vital functions and its structural organization is adapted to these conditions, we could expect

...it greater atrophy there than in other regions with removal of weight. Nevertheless, overall evaluation of the submitted data warrants the belief that the range of loss of spongy bone when the skeleton does not support any weight constitutes a mean of about 35% and is regulated by genetic mechanisms.

Since precise methods of assessing the density of spinal bones are presently only at the developmental stage [29, 30], the question arises of possibility of using ordinary roentgenography to detect vertebral osteoporosis when there is 35% atrophy of structure.

The results of our studies indicate that the density of structural elements in the vertebral bodies, as assessed by the mineralization parameter, fluctuates over a wide range (from 0.135 to 0.310 g/cm^3) in healthy adults 20-50 years of age. For this reason, even marked atrophy in individuals with high mineralization does not necessarily lead to rarefaction of structure to the level that characterizes the bottom range of individual variability and, consequently, cannot be diagnosed roentgenologically as osteoporosis. It is not by chance that, of the 6 neurological patients we surveyed, which had been on bed rest for up to 13 months, only three revealed vertebral osteoporosis when examined roentgenologically. Nevertheless, the demonstration of osteoporosis roentgenologically at the above times confirms the high rate of atrophic changes in the spine.

Thus, the results of our studies and data in the literature confirm the validity of the proposed model of atrophic changes in spongy structures of the axial skeleton when it supports no weight. A good agreement was obtained between estimated figures and parameters determined by special tests of loss of bone mass in the calcaneus and ilium, proximal femoral metaphysis and the spine. The data referable to this model indicate that the most rapid resorption of bone occurs in the spine which, moreover, contains most of the spongy bone of the entire axial skeleton. Consequently, a negative calcium balance is attributable to a significant extent to atrophic changes in expressly the spine. It is not by chance that a negative calcium balance was not demonstrated in 30 subjects who were kept on bed rest for 30 days, because they were allowed to sit up [32].

Considering the fact that processes of atrophy of spongy structures stop at a relatively early stage (essentially before 1 year is up), the negative calcium balance which persists after this time [33] is apparently due to resorption of compact bone.

In conclusion of our discussion of the intraspecific model, it must be noted that absence of a load during bed rest has the same effect on all parts of the axial skeleton. Passive muscle tone virtually fails to raise the internal tension in the spine [34]. This circumstance serves as additional validation of the choice of both the model in question and the interspecific model of bone atrophy, which also permits evaluation of the rate of resorption of different bone structures, as well as to do so in relation to the mechanical properties of bones of man and different animals. Since these properties are determined by the state of the mineral phase of bone structures [28, 36], its parameters in animals and man were compared. The data listed in Table 2 are indicative of appreciable interspecific differences in mineralization of the structures tested, with less marked difference in mineralization and concentration of

principal elements (calcium and phosphorus) contained in crystalline and amorphous substances.

Table 2. Parameters of mineral phase of spongy bone

BIOL. SPEC.	BONE	MINERALIZATION G/CM^3	ASH, %	LEVELS PER 100 G ASH			
				CALCIUM G	PHOSPHORUS G	SODIUM MG	POTASSIUM MG
MAN	VERTEBRAL BODY	0,218±0,003	46,0±0,20	42,70±0,33	11,30±0,09	601,0±[illegible]	64,2±2,0
DOG	DISTAL EPIMETAPHYSIS OF FEMUR	0,253±0,009	59,18±0,62	41,13±1,30	14,[illegible]±0,51	51[illegible],0±42,2	44,9±[illegible]
RAT	HEAD OF FEMUR	0,[illegible]±0,011	60,0±0,60	43,5[illegible]	17,2±0,37	[illegible]	40,0±1,1

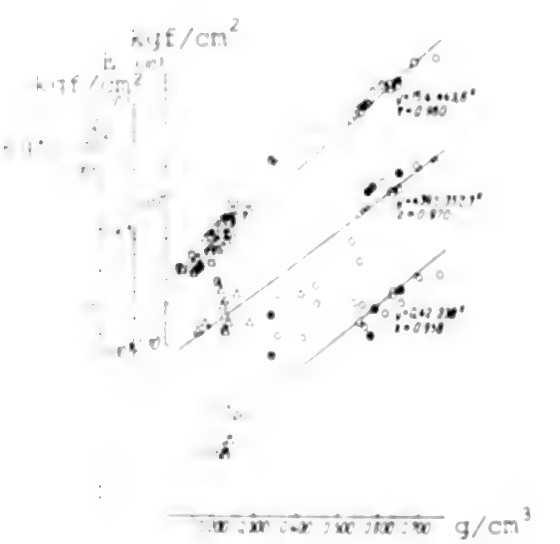

Figure 3.
Mechanical properties of spongy bone as a function of its mineralization. Triangles--human vertebrae; squares--distal epimetaphysis of canine femur; circles--head of rat femur (average data for groups). X-axis, mineralization; y-axis, range of strength (σ), modulus of elasticity (E), energy of elastic damping [shock absorption] (α). Cross-hatched symbols--bones with osteoporosis; symbols with dot in center--bone structures after readaptation period,

It must be noted that the degree of mineralization and quantitative characteristics of mineral composition are taken into consideration in an integral parameter of mineralization, which also reflects the compactness of trabecular structures. It is not by chance that the dynamic strength of the human spine, which we tested on segments with a pulse of 50-70 ms, static strength of the vertebrae, as well as static strength of spongy structures in dogs (distal epimetaphyseal region of femur) and rats (head of the femur) are exponential functions of mineralization.

The modulus of elasticity and energy of elastic damping have an analogous relationship to mineralization.

Figure 3 illustrates in general form the static mechanical properties as a function of mineralization. As can be seen in Figure 3, the illustrated functions are universal in the interspecific aspect--for both normal and osteoporotic spongy structures. In other words, the structural density of spongy bone is the main parameter to determine its mechanical properties. The exponential nature of the shown functions is indicative of substantial change in parameters of mechanical properties with relatively minor fluctuations in mineralization. Thus, strength of the head of the rat femur diminished by 20-40% as a result of 5-20% thinning of structure during

[illegible] spaceflights, whereas in dogs, the strength of spongy tissue of the [illegible] perimetaphyseal region of the same bones decreased by more than 60% in the course of a 90-day model experiment (rarefaction of 33%).

The data obtained concerning decrease in strength of spongy structures of the turtle during spaceflight [19] and human vertebrae during bed rest [37], regardless of mineralization, require additional scrutiny. In the course of 20-40 days of bed rest, the concentration of calcium in the mineral component of human vertebrae diminished without overt signs of development of osteoporosis in them. This fact indicates, in the first place, that the calcium lost from bone at the relatively early stage of lack of weight-bearing is predominantly metabolic rather than structural, of the bone surface in the hydrate layer of crystals open to exchange. In the second place, loss of even this calcium weakens the strong hydrogen and ion bonds between the collagen macromolecule and crystal, which diminishes the hardness of the collagen-crystal composite and, consequently, the mechanical properties of bone. The theoretical validation of the possibility of such processes is given in [38, 39]. However, their significance to mechanical properties can apparently be manifested only at the early stages, whereas with development of osteoporosis the decrease in strength of spongy structures is related entirely to severity of the former.

With reference to the data in Table 2, it must be noted that the parameters it lists for the mineral phase of bone also reflect the rate of physiological remodeling of bone, at any rate within a biological species. When there is rapid renewal, part of the de novo formed substance does not reach a high degree of mineralization; there is no time for the hydroxyapatite crystals to reach a maximum, and this determines the typical quantitative indicators of element composition for such rates of renewal (calcium, phosphorus, sodium, potassium). Conversely, when there is slow new bone formation, mineralization reaches high levels and there are different quantitative indicators for its elements.

In validating the approach to building an interspecific model of bone atrophy, we must mention the relative rate (y, percentile) as a function of density of structure (x, in grams/cm^3) which we established. There is an inverse link between these parameters: for rats, $y = 55.39-72.61x$ with a coefficient of correlation (r) of -0.678; for dogs, $y = 22.04-42.25x$ with $r = -847$. Such a relationship could reflect the correlation between structure density and rate of physiological renewal, taking also into consideration the degree of mineralization of bone and element composition of the mineral component.

Thus, the parameters of the mineral phase of bone that we studied determine both its mechanical properties and severity of atrophic changes in the absence of a weight load. Moreover, the latter is related to intensity of metabolic processes in the body. This warrants consideration of these parameters in the same interspecific system of analysis [43].

Interspecific relations between averaged biological parameters were studied with additional use of reference data on basal metabolism [44] as a function of intensity of metabolism (Figure 4a). This figure shows that the logarithms of functions of values of mineralization of bone and mineral composition are virtually at zero (for the sake of simplicity they are designated by the same

symbol), while the functions for parameters of mechanical properties differ substantially. The median of the angle formed by these two groups of parameters represent the logarithms of correlations [functions] between mineralization, intensity of metabolism and basal metabolism.

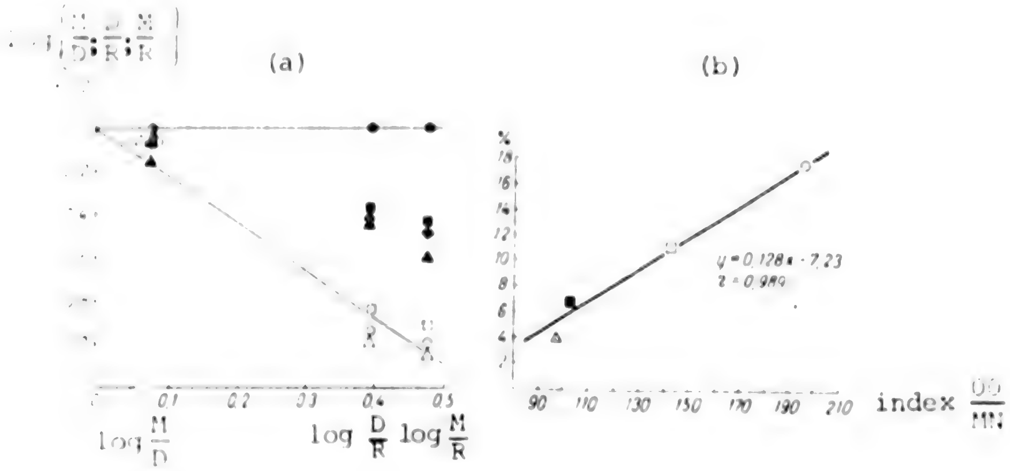

Figure 4. Interspecific indicators of biological parameters of man (M), dogs (D) and rats (R)

a) logarithms of ratios (M/D, D/R, M/R as a function of intensity of metabolism: black circles--ash content, concentration of calcium, phosphorus, potassium, sodium; triangles--basal metabolism; squares--mineralization; rhombus--intensity of metabolism. White symbols: range of strength; triangles--modulus of Young, square--specific energy of elastic deformation
b) rate of atrophy of bone structures (%) as a function of relative index of basal metabolism (00)/mineralization (MN); triangle--man, black and white squares--dog, circle--rat

Proceeding from the hypothesis that the change in a biological parameter under the influence of an extreme factor (in this case, absence of support function of skeleton) is proportionate to species-specific variability and attributable to its effect, we can determine the rate of atrophy of spongy bone in man when the rate of atrophy is known for dogs and rats. The fact that we used indicators for analysis that were referable to different parts of the skeleton of different biological species is irrelevant, since overall consideration of these parameters determines the rate of atrophy of a concrete spongy structure.

Since mineralization and basal metabolism integrally characterize the properties in question (they form the median of the angle illustrated in Figure 4a), but have different significance to rate of atrophic changes, it becomes meaningful to compare it to the index characterizing the reciprocal of the product of mineralization multiplied by basal metabolism.

In rats, mineralization of the distal epiphysis and head of the femur, as well as rate of resorption of bone in these regions, were about the same. For this

[illegible], we took into consideration the mean indicators for these parts of bone (0.2[illegible] g/cm³ and 17.8%/month, respectively). In dogs, mineralization of bone of the distal epimetaphyseal region constituted 0.253 g/cm³ with 11%/month atrophy, and for the head of the femur the figures were 0.372 g/cm³ and 6.2%, i.e., the parameters differed appreciably and for this reason were recorded separately. The function plotted in this manner (Figure 4b), which includes the corresponding average monthly indicators of atrophy of spongy structures in rats, dogs and the human calcaneus, becomes linear without prior logarithmization of values plotted on the x- or y-axis. The rate of atrophic changes for the calcaneus that we used (3.9%) was obtained on the basis of testing six individuals who had maintained bed rest for 20 days [21], while its average mineralization constituted 0.260 g/cm³ according to our data. One can forecast the individual rate of atrophy of spongy structures by estimating these data in each specific instance and using the above equation. The average monthly intensity of atrophy in the spine determined in this way coincided with the analogous indicator obtained with use of the intraspecific model.

Thus, the rate of atrophic change in spongy structures of the human axial skeleton, which was determined by two independent methods (on the basis of intra- and inter-specific models), showed good agreement and was consistent to direct measurements. The intraspecific model for the human population is based on the rate of physiological renewal of various spongy structures of the skeleton and the interspecific model, on indicators that determine this rate: density of bone structures and intensity of metabolism. We cannot rule out the possibility that the level of metabolic processes also determines bone structure density. The submitted data make it possible to predict the degree of decline in endurance of head-pelvis impact accelerations as a function of spaceflight duration.

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UDC: 629.78:612.1

HEMODYNAMIC DISTINCTIONS RELATED TO DIFFERENT MODELS OF EXPERIMENTAL HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 27 May 82) pp 45-48

[Article by O. P. Dobromyslova, L. A. Pokrovskaya and S. A. Levshin]

[English abstract from source] The effect of hypokinesia on systemic hemodynamics has been investigated in rat and rabbit experiments using dispersion analysis. It has been shown that different models of hypokinesia produce hemodynamic disorders which depend on the type and duration of hypokinesia and animal responses to them. In rats the exposure to hypokinesia causes the hypertensive symptom-complex while in rabbits hypotensive disorders. The application of the dispersion analysis allows quantitative estimation of the hypokinetic effect on demonstrative indexes and detection of the most vulnerable parameter.

[Text] Observations of humans and experimental studies established that restriction of motor activity elicits disorders referable to the cardiovascular system, which ultimately lead to pathological changes, which are functional at first and then also organic in nature [1, 2]. Our study was pursued with these investigations in mind, and we examined systemic hemodynamics in different models of hypokinesia, using variance analysis for quantitative evaluation of the factor involved.

Methods

We used two models of restricted motor activity: the first consisted of placing mongrel male rats (15 animals weighing 200-220 g) for 5 days in individual plexiglas cages, which limited movement in all directions; the second consisted of placing male rabbits (6 animals weighing 2.5-3.0 kg) in hypokinetic "body" cages which restricted movement to one-fourth the norm [1], keeping them there for 10 and 30 days. Rats [15] and rabbits[6] kept in ordinary vivarium cages served as a control. Experimental and control animals were kept in the same room, on the same complete diet and water ad lib. In order to assess hemodynamics at the end of each period of hypokinesia, in acute experiments, we recorded on all animals respiration, the electrocardiogram in the second lead, arterial (APO pressure in the abdominal aorta of rats and femoral artery of rabbits. We calculated the following parameters: respiration rate (RR),

heart rate (HR); AP: systolic (AP_s), diastolic (AP_d), pulse (AP_p), dynamic mean (AP_{dm}); duration of ejection phase (E), stroke volume (SV), minute volume (MV), total peripheral resistance (TPR). The obtained data were processed by the method of variance analysis of single-factor complexes [3]. Calculations were made using specially prepared programs on an Elektronika-B3-?? type microcalculator.

Variance analysis of the effect of hypokinesia on systemic hemodynamics with experimental simulation of this state consisted of examining the statistical influence of the factor of restricting motor activity of experimental animals on the above-mentioned parameters, which characterize the state of the cardiovascular system.

Results and Discussion

The results of experiments with 5-day hypokinesia in rats, which are illustrated in Figure 1a, indicate that HR, RR, all AP parameters, as well as E, SV and MV, were higher in animals submitted to hypokinesia than in the control; TPR, on the contrary, was lower than in the control.

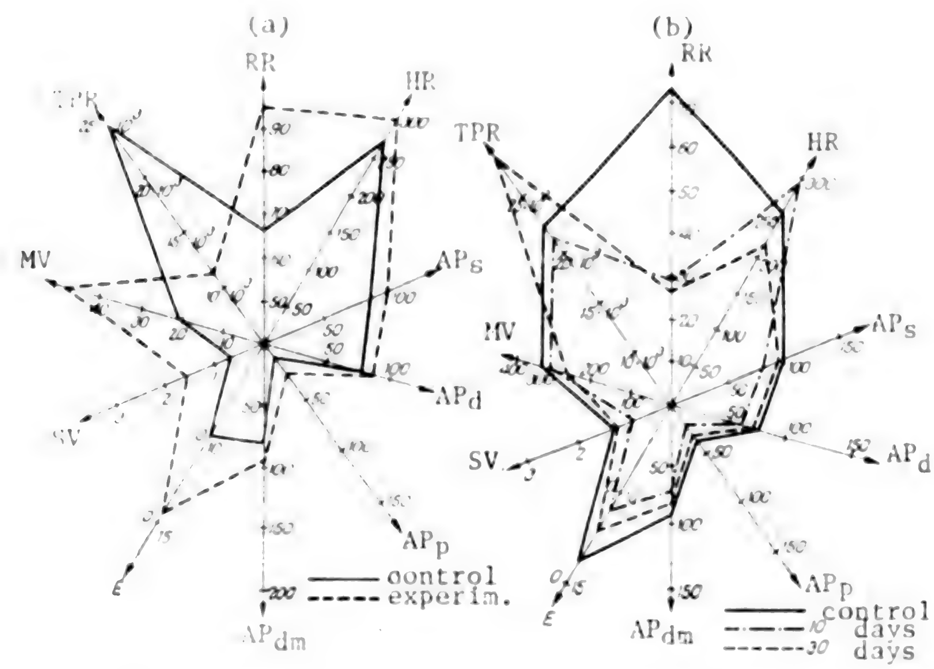

Figure 1. Changes in hemodynamic parameters of rats (a) and rabbits (b) under the influence of hypokinesia

1-10) RR, HR, AP_s, AP_d, AP_p, AP_{dm}, E, SV, MV and TPR, respectively.

Variance analysis, the results of which are submitted in the Table and Figure 2a, revealed that the tested factor had a strong effect on several parameters, namely, AP_s and AP_p, E, SV and MV, TPR. The results indicate that, in rats, hypokinesia had a reliable effect on the above parameters, with a threshold of probability of correct prognosis $\beta = 0.95$. A comparison of individual means of tested parameters in the variance complex of control

and experimental groups revealed that the differences between the above parameters were highly reliable.

Variance analysis of effect of hypokinesia on hemodynamic parameters of experimental animals

Parameter	Rats			Rabbits		
	$\eta_x^2 \pm m_{\eta_x^2}$	F	β	$\eta_x^2 \pm m_{\eta_x^2}$	F	β
RR	0,114±0,09	1,16		0,75±0,05	14,86	⩾0,99
HR	0,036±0,107	0,340		0,98±0,002	375,3	⩾0,999
AP_s	0,598±0,044	13,4	⩾0,99	0,24±0,1	2,37	
AP_d	0,055±0,105	0,52		0,06±0,12	0,503	
AP_p	0,89±0,01	77,4	⩾0,999	0,25±0,099	2,5	
AP_{dm}	0,29±0,07	3,72		0,09±0,012	0,732	
[illegible]	0,9±0,01	85,1	⩾0,999	0,25±0,1	2,44	
SV	0,83±0,01	43,8	⩾0,999	0,26±0,09	2,6	
MV	0,48±0,05	8,37	⩾0,95	0,09±0,12	0,738	
TPR	0,75±0,03	26,4	⩾0,999	0,11±0,11	0,94	

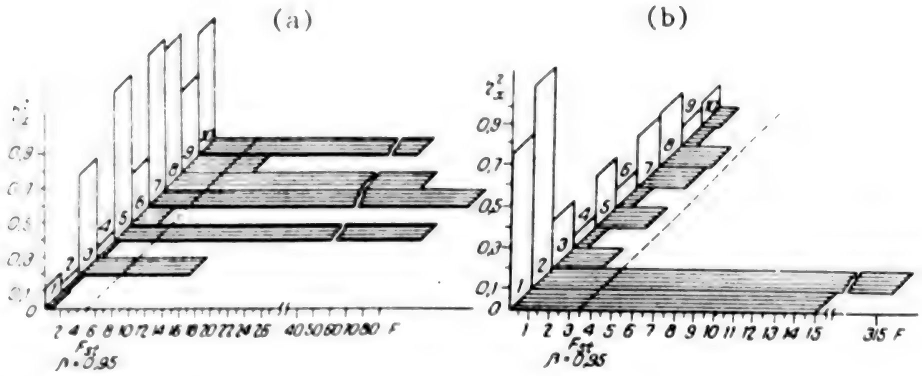

Figure 2. Evaluation of effect of hypokinesia factor on hemodynamic parameters of rats (a) and rabbits (b)

η_x^2) force of effect of factor

F) reliability of force of effect

F_{st}) standard values of Fisher's criterion

β=0.95) threshold of probability of error-free prognosis [forecast]

a) solid line--control, dash--experiment

b) solid line--control, dash-dot--10th day of experiment, dotted line--30th day of experiment

The results of experiments with 10- and 30-day hypokinesia in rabbits, which are illustrated in Figure 1b, indicate that in the experimental animals the tested parameters were lower than in the control, with the exception of TPR, which was higher in rabbits submitted to hypokinesia for 30 days than in control animals. A comparison of individual means of the tested parameters of experimental and control animals revealed that, after 10-day hypokinesia,

The rabbits presented a reliable decline of the following parameters: RR, HR, [illegible], i and SV. However, variance analysis revealed that the hypokinesia factor had a strong effect only on RR and HR (Figure 2b, see Table), i.e., in spite of the difference in means for the control and experiment with 10-day hypokinesia the effect of this factor on rabbits was reliable (with probability [illegible] 0.95) only for two parameters, RR and HR.

Two conclusions can be derived from the facts submitted above: 1) hypokinesia has a substantial effect on systemic hemodynamics of experimental animals; 2) the nature of this effect depends on the model of hypokinesia (animal species, extent and duration of restricted motor activity). The models we chose led to opposite changes in hemodynamics: rats developed hypertension whereas rabbits, on the contrary, had a tendency toward developing hypotension. One can attribute development of hypertension in rats to the tension reaction, which is a response to the effect of hypokinesia that is, as we know, a stress factor for this species of animals [4, 5]. According to the obtained data, the hypertensive reaction develops in rats in the cardiac pathogenetic form [6], where the increase in MV is associated with decrease in TPR. As for the hypotensive reaction of rabbits, it can be interpreted as natural adaptation of hemodynamics to conditions of diminished motor activity. The hypotensive effect of 10-day hypokinesia in rabbits is attributable to diminished pumping capacity of the heart [7], i.e., in rabbits hypokinesia elicits development of the cardiac pathogenetic form of change where there is decline of MV with hypotension, with unchanged TPR. The fact that no further changes occurred in the parameters when hypokinesia was extended from 10 to 30 days is indicative of a natural adaptive reaction of the body, as well as that hemodynamic adaptation to restricted motor activity occurs within the first 10 days.

Dependence of hemodynamics on the model of hypokinesia must be taken into consideration when comparing data obtained for different animals, with different degrees of restricted movement, duration of such hypokinesia, as well as in explaining the causes of differences in endurance and reactions of the human cardiovascular system to hyperkinesia [sic].

Another conclusion is drawn from the results of variance analysis: this method of statistical processing enables one to make a deeper and more substantiated judgment about the efficacy of the factor in question. Thus, in the experiments on rabbits, a comparison of special [individual] means in the control and experimental groups revealed a reliable decline of six of the parameters characterizing hemodynamics; with use of variance analysis, however, a reliable effect of the hypokinesia factor was demonstrated only for two parameters. Use of variance analysis makes it possible to evaluate quantitatively the effect of the factor in question on the resultant signs and demonstrate the most vulnerable parameter to this factor.

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STRUCTURAL AND FUNCTIONAL CHANGES IN HUMAN ERYTHROCYTES AND LEUKOCYTES RELATED TO SEVEN-DAY IMMERSION HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 22 Apr 82) pp 48-51

[Article by G. I. Kozinets, M. S. Belakovskiy, A. S. Ushakov, I. A. Bykova, V. P. Matveyenko, S. M. Dul'tsina, O. A. Dyagileva, V. V. Kasatkina, I. V. Ryapolova and V. M. Pogorelov]

[English abstract from source] Changes in blood parameters (red and white blood cell counts) were examined in 6 healthy male volunteers during an acute stage of adaptation to the exposure simulating physiological effects of weightlessness. The parameters varied, remaining, however, within the physiological limits.

[Text] Spaceflight conditions cause functional changes in a number of human organs and systems. Redistribution of blood, hemodynamic shifts, changes in fluid-electrolyte metabolism and others have been observed [1, 2]. There are also changes in the blood system [3-6]. In this regard, it is interesting to investigate the dynamics of changes in blood parameters (erythrocyte and leukocyte counts) in the acute period of adaptation to conditions simulating some of the physiological effects of weightlessness.

Methods

We used the model of "dry" immersion developed by Ye. B. Shul'zhenko [7] as a factor simulating one of the principal effects of spaceflights--weightlessness. The tests were conducted in a special tank 200×100×100 cm in size. A waterproof sheet ["film"] was placed on the water surface, and it was of the same size as the tank, while its mass was the same as that of the fluid. This fabric sheet served the role of a barrier separating the subject from the liquid. Water temperature in the tank was 33°±0.5°C. The subject was immersed in the tank up to the neck, in horizontal position.

The daily schedule consisted of 8 h sleep, three regulated meals, a program of clinicophysiological monitoring [checking], personal time (viewing television programs, reading, making entries in logs). We tested 6 healthy men 25 to 35 years old. The subjects were submitted to immersion hypokinesia for 7 days.

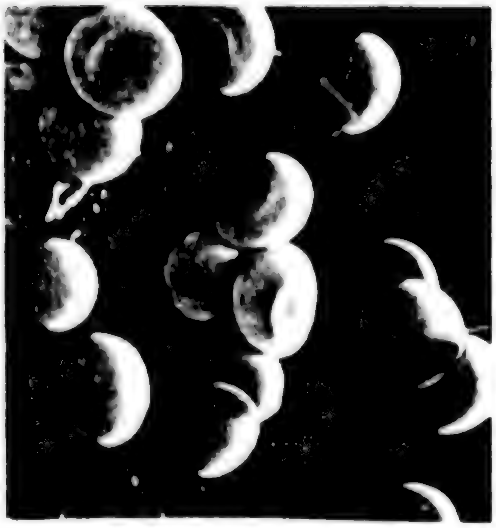

Figure 1.
Seventh day of immersion hypokinesia. Discoid, dome-shaped and spherical forms of erythrocytes; magnification 3000×

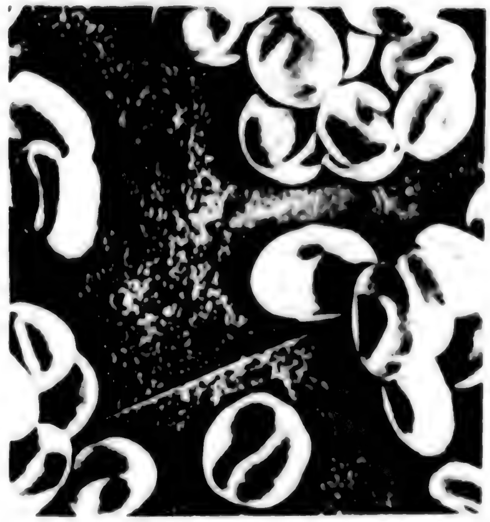

Figure 2.
Second day after immersion hypokinesia. Discoid forms of erythrocytes; magnification 3000×

We evaluated the functional and structural properties of erythrocytes using the following tests: determination of blood hemoglobin and erythrocyte count; interferometry of erytrhocyte, estimating their percentile distribution as a function of dry mass [8]; age, composition of erythrocytes on the basis of analysis of acid hemolysis erythrograms [9]; determination of deformability of erythrocytes by testing the process of their filtration through a filter with 5 μm pores on polycarbonate membranes [10]; examination of shape and surfaces of erythrocyte architectonics by the method of scanning electron microscopy [11].

Functional properties of leukocytes were evaluated by means of the following tests: leukocyte count and leukocyte formula; cytochemical demonstration of alkaline phosphatase, myeloperoxidase and polysaccharides in granulocytes and polysaccharides in lymphocytes; blast transformation of lymphocytes in 3-day cultures of peripheral blood with phytohemagglutinin (PHA); analysis with differentially stained metaphases of chromosomes in cells of peripheral blood cultures (PHA) with use of semiquantitative evaluation of regions of centromere heterochromatin (c-segments) according to arbitrary size and position on the chromosome.

Results and Discussion

Table 1 lists the results of determining the concentration of blood hemoglobin, erythrocyte count and mean hemoglobin content per erythrocyte before the study, on the 2d and 7th day of immersion hypokinesia and on the 2d day of the recovery period.

Table 1. Hemoglobin and erythrocyte content in the course of 7-day immersion hypokinesia

Parameter	Time of examination	M±m	Range
Blood hemoglobin concentration, g/l	before start of immersion	154±6	130-178
	2d day of immersion	145±12	120-162
	7th day of immersion	170±3	159-174
	2d postimmersion day	164±10	149-184
	physiological norm		132-164
Blood erythrocyte count, millions/μl	before start of immersion	5.3±0.2	4.5-5.8
	2d day of immersion	5.4±0.2	5.2-5.9
	7th day of immersion	5.6±0.05	5.5-5.8
	2d postimmersion day	5.3±0.1	5.1-5.2
	physiological norm		4.0-5.2
Hemoglobin content per erythrocyte, pg	before immersion	29±0.5	28-31
	2d day of immersion	27±0.3	27-28
	7th day of immersion	30±0.6	29 31
	2d postimmersion day	31±1.1	29 33
	physiological norm		27-34

As can be seen in Table 1, no deviations of tested parameters from normal physiological values were demonstrable with 7-day immersion hypokinesia. The increase in erythrocyte count and hemoglobin concentration in some cases reflects the phenomenon of "thickening of blood" as a result of impairment of fluid-electrolyte balance under the effect of hypokinesia.

In addition to the above studies, interferometric determination of dry erythrocyte mass was made. In view of the fact that this technique permits measurement of dry mass of each individual erythrocyte, data were obtained on percentile distribution of erythrocytes as a function of their solid matter content. The dry erythrocyte mass is normally 95.5% dependent on hemoglobin content and only 4.5% is referable to nonhemoglobin proteins, enzymes, polysaccharides, lipids, salts and other components. One can assess the patterns of hemoglobinization on the cellular level from the percentile distribution of erythrocytes as a function of solids (hemoglobin). The results of these studies are listed in Table 2.

As can be seen in Table 2, the percentile distribution of erythrocytes as a function of their dry mass did not differ after 7-day immersion hypokinesia from the results of a test made before the start of this experiment and the normal parameters inherent in healthy males.

There were no deviations in age-related composition of erythrocytes or parameters of deformability of erythrocytes, which reflect membrane elasticity.

Table 2. Percentile distribution of erythrocytes as a function of dry mass with 7-day immersion hypokinesia, "tm

[illegible] time	Percentile distribution of erythrocytes as a function of their solid substance content			
	[illegible]	[illegible]	[illegible]	[illegible] & over
[illegible] and	24.4±2.1 (18–30)	55.2±3.9 (46–68)	19.7±2.1 (12–24)	0.7±0.4 (0–2)
After 7-day immersion	23.0±3.4 (20–29)	56.4±3.6 (50–70)	20.3±1.4 (16–24)	0.3±0.2 [illegible]
Normal parameters for healthy males	16±2.5 (4–26)	61±3.0 (47–75)	22±2.6 (10–36)	1±0.8 (0–7)

Note: Range of fluctuation is shown in parentheses.

Scanning electron microscopy revealed that the shape of erythrocytes was subject to dynamic changes during 7-day immersion hypokinesia. In all subjects, there was marked reduction in discoid forms of erythrocytes and increase in dome-shaped erythrocytes, in the form of a collapsed ball, spherocytes, by the 7th day (Figure 1). On the 2d day of the recovery period there was normalization of erythrocyte shapes (Figure 2).

Leukocyte counts at all stages of the study revealed that immersion hypokinesia did not have an appreciable effect on blood leukocyte content. The white blood cell formula also remained normal.

Cytochemical studies of myeloperoxidase (the marker of secondary neutrophil granules), as well as polysaccharides, in granulocytes failed to demonstrate deviations from normal levels when reactions were tested on the 2d and 7th days of immersion, as well as the 2d day of the recovery period.

Cytochemical demonstration of polysaccharides in lymphocytes on the 7th day of immersion, as well as 2d day of the readaptation period, revealed some increase in PAS-positive lymphocytes and intensity of reaction. The mean cytochemical coefficient (CCC) increased by 1.5 times, as compared to control values. This is consistent with the results of testing blast transformation of lymphocytes in 3-day cultures with phytohemagglutinin. We demonstrated greater blast transformation in all tested samples on the 7th day of hypokinesia ([illegible]±5.0), as compared to the base value (55.9±5.8). These figures did not, however, exceed the normal range of fluctuation of this parameter (42.0-74.4).

Cytogenetic analysis revealed that the distribution of the c-variant with arbitrary size of c-segment in a reference sample of homologues of the 1st and 16th pairs of chromosomes was homogeneous in cells of peripheral blood cultures ($\chi^2 = 23.53$, $P<0.01$ and $\chi^2 = 27.32$, $P<0.01$). The homogeneity of distribution of c-variants of homologues of the 9th pair of chromosomes was questionable ($\chi^2 = 32.02$, $P<0.05$).

... the studied pairs of chromosomes were c-segments of average ... score of 2-3). Their share in the sample constituted 79.32% for the ... pair of chromosomes, 80.60% for the 9th and 71.16% for the 16th pair.

... asymmetry of the distribution curve was demonstrable when we ... the shares of extreme c-variants of homologues of the 1st, 9th and ... pairs of chromosomes, i.e., the c-variant scored at 1 and 4, for a total ... by means of z-conversion of Fisher and the u criterion for normal distribution.

As a rule, the c-segments of the chromosomes examined were demonstrable on the long arm of the chromosome.

Our data are entirely consistent with the parameters recorded in a cytogenetic ... of essentially healthy people.

Thus, the results of these studies warrant the belief that 7-day immersion hypokinesia has no pathological effect on structural and functional properties of erythrocytes and leukocytes in human peripheral blood.

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INVESTIGATION OF CORONARY CIRCULATION OF PILOTS DURING FLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 9 Jul 82) pp 51-54

[Article by V. S. Bednenko, A. B. Vasil'yev, A. N. Kozlov and V. Ya. Kolyagin]

[English abstract from source] Coronary circulation was examined in pilots of transport aircraft during 14 flights by Doppler cardiography (with respect to changes in the integrated level of the reflected signal in systole). At certain flight stages the coronary circulation efficiency varied substantially. It is concluded that coronary circulation should be monitored during pilot training and aircraft testing in order to standardize flight loads.

[Text] It is important to assess the functional state of the cardiovascular system of flight personnel during flights in order to evaluate pilot fitness [work capacity], prevent fatigue and overfatigue and preserve long-term fitness for flying [1-3]. However, the possibilities of studying cardiodynamics in flight are limited [3]. Our objective here was to investigate coronary circulation as a function of difficulty of flight assignment. For this purpose we used ultrasound Doppler cardiography (USDC), which permits determination of dynamics of efficient coronary blood flow (EBF) during operator work [4-6].

Methods

The studies were conducted during 14 flights in transport aviation aircraft, with test pilots performing diverse flight assignments: horizontal flight (HF) in modes of manual (MC), semiautomatic (SAC) and automatic (AC) control with and without a distracting task (DT), approaches to landing in the same modes and landings. USDC was recorded on the commander by means of a developed system of placing a sensor [7], from a region that enabled us to locate the posterior wall of the left ventricle (4th intercostal space on the left, near the sternum). Concurrently, we recorded the electrocardiogram (EKG) in the D-S lead and pneumogram (PG). We used the KMA-72 equipment and an onboard magnetic storage unit to record these parameters.

Duration of cardiac (t_c) and respiratory (t_r) cycles, heart rate (HR) and respiratory rate (RR) were determined from the EKG and PG. From the USDC we

Table 1. Hemodynamic parameters of pilots during flight (M±m)

Parameter	Horizontal flight					Landing approach with pass				Landing
	MC "blind"	AC	SAC	MC with DT	SAC with DT	MC "under hood"	AC	SAC	MC with DT	
t_c, s	0,74±0,03	0,86±0,11	0,80±0,03	0,73±0,03	0,80±0,04	0,65±0,02	0,77±0,05	0,65±0,02	0,71±0,05	[illegible]
t_r, s	2,77±0,17	3,07±0,20	2,92±0,21	2,83±0,20	3,13±0,20	2,34±0,12	2,51±0,14	2,77±0,27	2,05±0,04	2,07±[illegible]
Q	1,32±0,10	1,00±0,14	1,23±0,11	1,26±0,21	1,17±0,14	1,60±0,19	1,37±0,27	1,50±0,22	2,34±0,47	1,73±0,44
K	1,47±0,22	1,00±0,18	1,30±0,15	1,46±0,22	1,24±0,15	2,10±0,20	1,38±0,39	1,97±0,31	2,83±0,71	2,68±0,69
W	1,94±0,36	1,00±0,24	1,54±0,41	1,10±0,39	1,58±0,35	4,00±0,96	2,31±0,35	4,11±1,06	7,59±2,09	7,59±1,08

assessed dynamics Q of efficient stroke coronary blood flow (EBF), which reflects the amount of blood flowing through coronary vessels that gives off oxygen into the myocardial capillaries [4]. To assess EBF, we used a method that we developed for determining Q from the integral level of the signal reflected from the posterior wall of the left ventricle in systole [4-6]. The integral value of the signal was determined using an analogue converter of amplitude and frequency components of the USDC, according to duration of cardiac cycles [8]. We calculated the relative changes in EBF minute volume K as $K = Q \cdot f$, where f is change in HR.

We determined the overall parameter W of dynamics of amplitude and frequency components of USDC characterizing the energy of the signal in the tested volume [9], using the formula:

$$W = V' \cdot A'$$

where $V' = \frac{V_{cc}}{tc}$ is average rate of movement of the myocardial segment during the cardiac cycle,

$A = \frac{Q_{cc}}{tc}$ is mean parameter of elastoplastic properties of the myocardium (reflectivity of the region), V_{cc} and Q_{cc} are the integral parameters of frequency and level of USDC signals within the cardiac cycle.

In order to make it possible to compare the parameters recorded dynamically on different pilots, all of the parameters were normalized in relation to background data, which consisted of the values obtained at the HF stage with automatic control, since performance of this phase of flight involved the least difficulties for pilots.

[illegible] data, it was deemed expedient to assess the [illegible] of each parameter. We used rating B of the degree of certainty [illegible] (coefficient of multiple correlation) and number O of wrong [illegible] with successive exclusion of parameters, as criteria of informative [illegible]. The values of these criteria were determined using known methods [10]. [illegible] were calculated for HR and SV on the basis of their mean values, as well as individual increments (ΔHR and ΔSV) calculated for each pilot.

Results and Discussion

Tables 1 and 2 list our results. Analysis thereof revealed that the value of [illegible] CBF increases in flight. In different modes of horizontal flight the [illegible] constituted a mean of 17-32%, it was 37-134% during landing approaches and [illegible] during landings. When flying in the automatic control [illegible] there were moderate changes in CBF, whereas with manual control and [illegible] (tracking task) they were significant. Maximum CBF was observed [illegible] on approach for landing with DI and manual control.

Table 1. Changes in certainty (ΔB) and number of wrong decisions (ΔO) with successive exclusion of parameters

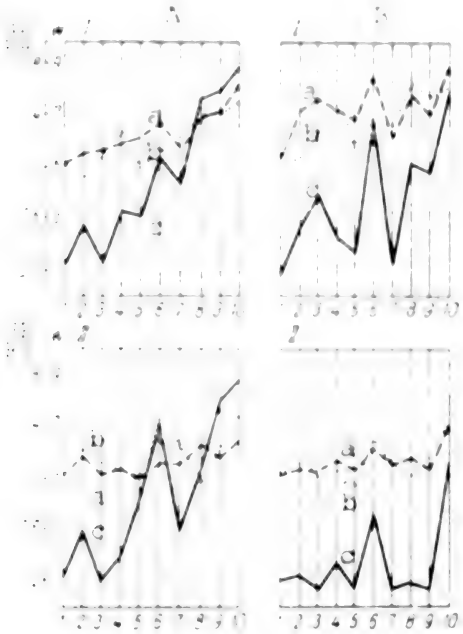
[illegible]	Horizontal flight		[illegible]—landing		Landing approach—landing	
	ΔB	ΔO	ΔB	ΔO	ΔB	ΔO
[illegible]	0.003	[illegible]	0	0	[illegible]	0
[illegible]	0	[illegible]	0	0	[illegible]	[illegible]
[illegible]	−0.004	[illegible]	0	0	[illegible]	0
[illegible]	0	0	0.067	−1.4	[illegible]	−1.5
[illegible]	[illegible]	[illegible]	0.078	1.4	[illegible]	−4.7

Note: $\Delta B = B_i - B_0$, $\Delta O = O_i - O_0$, where B_0 and O_0 are values of parameters calculated from the complete set of inflight parameters; B_i and O_i are values of the parameters with exclusion of *i*th parameter.

[illegible] of CBF were characterized by 24-47% increase in horizontal flight, [illegible] increase in landing approaches and 163% during landings. The severity of changes as a function of flying mode were similar for minute and stroke CBF. The increase in minute CBF was attributable more to increase in stroke coronary flow and, to a lesser extent, HR.

It is known that one of the most important distinctions of flight work in modern aircraft is the pilot's emotional stress [3, 11]. For this reason, as [illegible] the flight assignment performed in transport aircraft, we related the parameters primarily to this factor. This thesis is confirmed by the appreciable increase that we demonstrated in stroke coronary blood flow at several stages of flight and, as noted by the authors of [12], it occurs primarily when there is prolonged nervous and emotional tension, and it is [illegible] less marked when there are changes in spatial position of the body or physical load. In addition, the CBF changes demonstrated in flight were in the same direction and in the same range that are inherent in a

...of emotional states, according to data in [12, 13], and they are ...observed in the second phase of the reaction of coronary circulation.



Dynamics of HR (a), RR (b) and parameter of USDC signal (W) (c) in pilots

I) pilot B-iy (A--morning, B--evening)
II) Sh-v
III) T-v

X-axis, stages of flight:

1-4) HF (1--AC, 2--MC "blind"* 3--SAC, 4--MC with DT)
5-9) landing approaches with passes (5--AC, 6--MC "under hood," 7--SAC, 8--MC with DT, 9--SAC with DT)
10) landing

Evidently, marked dilatation of coronary vessels, which is typical in different stress states [12], is one of the prime mechanisms of EBF regulation. Moreover, the increase in cardiac output is also of appreciable significance, and it is significant at most stages of flight as shown by the results of our previous studies [14].

The dynamics of parameter W, which reflects change in energy of USDC signals [9] and depends on the state of coronary circulation, cardiac output and force of cardiac contractions were found to be the most informative in distinguishing between levels of reactions inherent in different stages of flight (Table 2). Exclusion of W from the base set of parameters elicits the greatest decline of B and greatest rise of Q.

There were also typical individual differences in values of Q, K and W in pilots (see Figure). A comparison revealed that, with commensurate values of W, pilot B-iy performed the different flight stages with a greater load on the heart than pilots Sh-v and T-v. The same pilot demonstrated lower increment of Q, K and W in an evening flight at stages of moderate difficulty than in a morning flight, which is apparently indicative of the fact that the pilot had reached optimum performance level [after the "work-in" period]. In pilot T-v, performance of all phases of flight was associated with a considerably lower increment of load on the heart than in B-iy and Sh-v. At the same time, performance of landings elicited approximately the same intensification of myocardial contractile function in all pilots.

*Translator's note: Russian expression is manual control "under hood" or "under curtain" and apparently refers to flying blind.

...tly, performance of the flight stages considered in transport aircraft ... distinct reactions of coronary circulation and a substantial increase ... on the heart. The demonstrated functional changes in the heart are ...ntly of a mobilization and compensatory nature. However, the emotional ... substantial significance to development of these changes. For ...ason, long-term and repeated repetition thereof during flight work ... associated with incomplete recovery of physiological functions and, ...ently, diminished work capacity, development of fatigue, as well as ... of coronary and cardiac insufficiency. To prevent these signs, ...irable to monitor coronary circulation and contractile function of ...ardium when refining flying modes and testing aircraft. The results of ...itoring would add to information about cardiac function gained by ...siological methods, and they would be useful in setting standards for flight work loads.

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DIAGNOSING FATIGUE IN FLIGHT PERSONNEL ACCORDING TO CARDIODYNAMIC DATA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 19 Apr 82) pp 55-58

[Article by V. S. Bednenko, G. N. Grechikhin, A. N. Kozlov and A. A. Krivonos]

[English abstract from source] By Doppler cardiography systolic and diastolic time intervals and cardiac contractility were measured in 22 pilots during interflight periods. Certain cardiodynamic parameters showed significant differences in the pilots as compared to 24 nonpilots. It is indicated that these parameters should be regularly monitored between flights in order to prevent fatigue of the flight personnel, to detect early development of cardiac insufficiency, and to maintain pilot longevity.

[Text] The professional activities of crews of flying vehicles involves exposure to a number of specific factors, and not infrequently this leads to functional changes in the cardiovascular system [1, 2]. Detection of such changes is of substantial relevance to prevention of fatigue in flight personnel, cardiovascular diseases and to assess pilot work capacity [1-3]. Since ultrasonic Doppler cardiography (USDC) [4] is one of the few techniques that permits evaluation of myocardial function in flight, it was deemed expedient to define the cardiodynamic distinctions of pilots in periods between flights, as compared to parameters for individuals in other occupations that do not involve flying.

Methods

We examined 22 grade I-II pilots with flying time of 700-750 h who had undergone routine certification in the medical flight commission, as well as 24 essentially healthy subjects in other occupations, who made up the control group. In all, we performed 135 examinations on days off from flying, at the same time of day, at rest. The age of subjects in both groups, main results of anthropometry and medical monitoring indicators did not differ reliably (Table 1). USDC was recorded from the projection of the left ventricle in the region of the 5th-6th intercostal space, near the sternum, in calm expiration; we recorded the direct signal on the Doppler cardiogram, as well as integral values of its amplitude (A) and frequency (F) for 8-10 cardiac cycles. Using a known method [5] based on typical amplitude and frequency of USDC, we

[illegible] analysis of cardiac function: we determined duration of atrial [illegible], [illegible] (T) and ejection (E) phases for the ventricles, proto- [illegible], relaxation (R), rapid and slow filling (RF and SF), [illegible] [illegible]. We calculated (As/Ad) and (Fs/Fd), [illegible] relationship between dynamics of elastoplastic properties of the myocardium and [illegible] parameters of motion in systolic and diastolic phases.

Table 1. Indicators obtained by anthropometry and medical monitoring of subjects (M±m)

Group	Ht., cm	Wt., kg	HD, kg	VC, cm^3	HR, /min	BP_s	BP_d
						mm Hg	
Pilots	173±1	71±2	62±2	4954±116	63±2	113±1	[illegible]
Control	174±2	70±2	65±1	4800±121	67±1	114±[illegible]	[illegible]

HD) results of hand dynamometry
VC) vital capacity of lungs
HR) heart rate
BP_s and BP_d) end systolic and diastolic pressure

Using the method of corrected spectral analysis of USDC, we calculated the rate of motion of the anterior (V_{ac}) and posterior (V_{pc}) walls of the heart in the region of localization from values of Doppler frequencies of typical spectral maximums; we determined the degree of these maximums (Γ_{pc}) and (Γ_{ac}) characterizing energy correlations between movements of the cardiac wall in systole and diastole [6].

Results and Discussion

According to our findings, there were no significant differences in duration of [illegible], P, RF and SF in pilots, as compared to the control group (Table 2). Duration of T period was reliably longer in pilots (by a mean of 11%). It was also somewhat above the mean value of this parameter, which we obtained in our preceding studies of individuals in other than flight occupations [5], but did not exceed the range of physiological changes in T in healthy subjects at rest. The incidence of higher values for the T period in flight personnel is apparently related to the greater physical conditioning of this occupational group, since analogous changes in phase structure of the cardiac cycle, which are adaptive in nature, have often been found in athletes and are typical of the "athletic heart" [7].

Duration of AS was reliably longer (by 21%) in pilots, and it was in the range of values found in essentially healthy people. Since many researchers have recognized that the atrial systole is hemodynamically highly efficient as the phase of active filling of the ventricles [7], it can be assumed that this difference is also attributable to the better physical conditioning of pilots.

There were no significant differences between the compared groups with regard to values of As/Ad and Fs/Fd.

Table 3. [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: [illegible] is reliable probability of difference in parameters between compared groups according to Student's [illegible] criterion. Here and in Tables 3 and 4, the asterisk shows [illegible].

Table 4. Amplitudes of components of corrected USDC spectra (M·m)

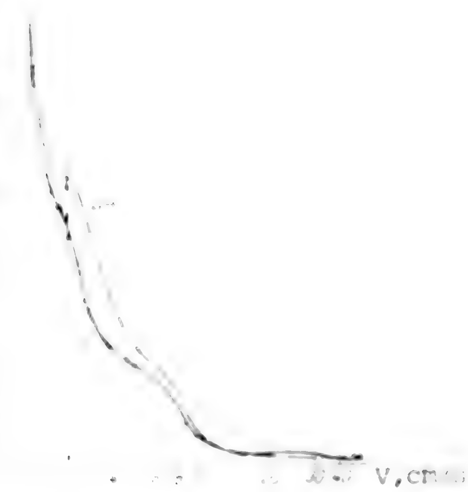
Group	V, cm/s													
	[illegible]	[illegible]	[illegible]	4.0	[illegible]	[illegible]	10.0	12.5	[illegible]	20.0	25.0	32.0	[illegible]	[illegible]
Pilots	[illegible]	[illegible]	[illegible]	0.2[illegible]±0.01	[illegible]±0.02	[illegible]	0.05±0.01	[illegible]±0.01	[illegible]±0.004	0.001±0.002	0.001±0.002	0.01±0.002	[illegible]	[illegible]
Control	[illegible]	[illegible]	[illegible]	0.2[illegible]±0.01	0.21±0.01	0.14±[illegible]	0.0[illegible]±0.[illegible]	[illegible]	0.02±0.002	0.02±0.001	0.02±0.002	0.02±0.002	[illegible]	[illegible]

Significant differences in USDC spectra were demonstrated in the range of velocity of motion of cardiac elements (2.6-3.2 cm/s) corresponding to motion of the anterior wall of the heart [6] (Table 3). The rate of its movement was reliably higher (by 18%) in pilots, while that of the posterior wall virtually failed to differ from parameters for the control group (Table 4). The higher values of V_{ac} should apparently be related primarily to the professional distinctions and work and rest schedule of flight personnel. The demonstrated changes in velocity parameters of cardiodynamics could hardly be attributed to degree of physical conditioning of pilots (unlike the changes inherent in the "athletic heart" in T and AS phase intervals), since no increase in rate of movement of the myocardium has been found in athletes [8]. These theses are based on existing data [8] concerning the distinctions of intracardiac hemodynamics, which were obtained in comprehensive studies of cosmonauts, an occupational group with a high level of adaptation to loads. In them, hemodynamics also presented some features inherent in athletes and, as noted by the author of the above-cited work, it was associated with a tendency toward hypertensive reactions.

The indicated changes in V_{pc} should be assessed as functional and adaptive, since opposite dynamics are typical of early preclinical stages of cardiac insufficiency--some decrease in rate of movement [9]; in the presence of various forms of cardiovascular diseases there is usually even greater decrease [10-13].

The level of the maximum of the USDC spectrum, which reflects motion of the anterior cardiac wall is substantially lower (by 44%) in pilots and is close to the bottom of the range of these parameter in the control group (see Figure). The demonstrated decline of parameter [illegible], which reflects the energy correlations

[illegible] wall movement in systolic and diastolic phases and [illegible] independent [illegible] value [6], was the most marked in flight personnel. [illegible] this basis, [illegible] assumed that the genesis of its changes is related to the [illegible] functional change in contractile elements of the [illegible] during [illegible] cycle, since the intensity of USDC signals is determined primarily [illegible] elastoplastic properties of muscle fibers involved in contractions [6, 14]. [illegible] are indicative of functional changes in the heart of flight personnel, [illegible] there is marked increase in parameter [illegible] [6] when there are disturbances in contractile function of the heart.



Examples of corrected USDC spectra recorded on flight personnel (solid line) and individuals in other occupations (dot-dash line).

The dotted line is exponential approximation.

S) amplitude values of spectrum components
V) velocity of movement of cardiac elements
ΔH) excess over spectrum maximum at approximation point
H) value of spectrum at indicated point

Table [illegible]. Parameters of degree of expression of spectrum maximums, amplitude and frequency components of USDC (M±m)

[illegible]	[illegible] ac	V_{ac}, cm/s	[illegible] pc	V_{pc}, cm/s	[illegible]s/Ad	[illegible]s/Fd
[illegible]	0.12±0.01	3.2±0.2	0.10±0.02	5.8±0.1	1.09±0.05	[illegible]
[illegible]	0.21±0.02*	2.7±0.1*	0.11±0.01	5.6±0.1	1.10±0.04	[illegible]

Thus, the pilots present some reliable distinctions of cardiodynamics, which are related to the specifics of flight work. For this reason, it would be desirable to pursue dynamic observation of changes in functional parameters of the heart in periods between flights. Prompt detection thereof could serve as a strong argument for prevention of pilot fatigue and demonstration of early stages of cardiac insufficiency.

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EFFECT OF TRANQUILIZERS ON MOTIVATION ELEMENTS AND TACTICS OF OPERATOR PERFORMANCE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 30 Oct 81) pp 58-62

[Article by G. D. Glod, I. S. Morozov, S. I. Sytnik, V. I. Morosanova and Ye. K. Ivanov]

[English abstract from source] The effect of tranquilizers on the motivation components and tactics of operator's activities was investigated, using a model of discrete tracking of a moving object. The correlation-matrix method was applied to determine the region of no error correction. It was shown that specific changes in the tactics of operator's activities developing in response to tranquilizers and reduced motivation were identical. It appears probable that decreased motivation of failure avoidance forms the phenomenon of preparedness of risk taking and optimization of operator's activities when tranquilizers are used under psychological conflict conditions.

[Text] There is a considerable number of studies of the effects of tranquilizers on various indicators of operator performance. In particular, it is known that tranquilizers have dissimilar effects on some elements of operator work performance under different conditions, as well as on their results [1-3]. In our previous studies in model experiments, we demonstrated an optimizing effect of some tranquilizers on aviation operator performance in the presence of increased psychoemotional stress [4-10]. One of the prime factors determining the dependence of the result of man's work on his emotional reactivity is largely referable to motivational processes when performing a given task [11, 12]. However, it is a methodologically difficult task to isolate the motivational component from the entire system of a complex behavioral act. Heretofore, there was virtually no objective method for quantitative evaluation of the level of motivation in performing some purposeful activity. This methodological problem can be solved on the basis of the conception that the level of motivation [intensity of motivation] determines the strictness of subjective criteria of achievement and the range of end results that are subjectively accepted by the operator and are not subject to correction by him in subsequent activity.

This study deals with the effects of several tranquilizers (phenazepam [benzodiazepine class], fenibut, mebicar), hypnosedative agents (sodium oxybutyrate)

[illegible] on the [illegible] attitude of subject[illegible] [illegible] of work, reproducibility of results of their [illegible] correction consistent with the accepted goal with [illegible] for reaching it and, if necessary, avoiding unsuccessful [illegible]. The results were compared to parameters of change in operator per[illegible] [illegible] particular, the parameters that characterize motivation elements) [illegible] levels of motivational stress.

[illegible]

[illegible] were conducted with the participation of 23 healthy individuals [illegible] men) 19-36 years of age (average age 22±1 years). We used [illegible] object moving in a clockwise direction--a light spot [illegible] of movement of the spot 25 cm in diameter, diameter of the spot [illegible], velocity of movement of the object 1.2 r/s, distance between object [illegible] 1.5 m) as a model of operator work. The subject's task was to [illegible] in its first pass [orbit] at a specific point on the [illegible] by depressing a button. The circumference was [illegible] equal positions, and after the button was depressed the [illegible] one of them. The subject had to perform two tasks in a [illegible] in the exact target (deviations to the left or right [illegible]) and to stop it at the target with a ban [illegible] of zero. Thus, conditions were created where, [illegible] task, there was dominance of motivation to succeed and in the [illegible], there was simulation of a conflict situation (combination of motiva[illegible] [illegible] unsuccessful actions). To raise the level of [illegible], we used a material reward of significance to the subjects [illegible] conditions. The subjects collected plus points [score] for [illegible] the target in both problems, and for each deviation to [illegible] one, there were penalty points. The rank they achieved [illegible] depended on the total plus and minus points. We excluded [illegible] situation and material reward to test performance against [illegible] motivation. Here the subjects performed in accordance [illegible] both tasks. In each task, we took 40 measurements [illegible] to the moving object. The obtained data were pro[illegible] [illegible]-matrix method, with determination of the range of [illegible] results for each subject, the position [illegible], as well as indicators of stability (coeffi[illegible] [illegible]), accuracy of correction (coefficient [illegible] (share of [illegible] target, at [illegible] determining the range of subjectively [illegible] of the above coefficients was described [illegible]. The range of uncorrected results can be viewed as the [illegible], and its limits characterize the strictness [illegible], and they are closely linked with the level [illegible] [11, 12]. The coefficient of reproducibility of [illegible] successive repetition of stopping the test object [illegible] of uncorrected results. The coefficient of [illegible] defined as the average share of correction of [illegible] stopping the test object in the zone of the subjective [illegible] consisted of the following. The subjects were first [illegible] until stable results were obtained in order to [illegible] training. The drugs were tested in the presence of

[illegible] (competition, material reward given after completion of the entire series of tests). In a separate series ([illegible] subjects who did not participate in the pharmacological part of the study), we tested operator performance at two levels of motivation. First the subjects performed the tasks immediately after being given verbal instructions, and on the following day they were told that they would receive a material reward in accordance with their performance and rank.

The psychopharmacological study was conducted by the double blind method. The agents (or placebo) were given once by mouth in random order (with [illegible]-day intervals between agents) 1 h before the test. The dosage of phenazepam was 0.001 g, fenibut 0.5 g, mebicar, 0.9 g, sodium oxybutyrate 2.0 g and sydnocarb 0.01 g. These doses were chosen with the expectation of manifestation of their specific psychotropic effects.

Results and Discussion

Table 1 lists data on the effects of the tested compounds on stability and accuracy of correction of results of operator work, which indicate that, in the tested doses, the tranquilizers enhance stability of performance, raise the coefficient of reproducibility of achievement in both tasks. The coefficient of reproducibility of results increased insignificantly after intake of fenibut and mebicar, and substantially after intake of phenazepam. Sodium oxybutyrate increased somewhat the stability of performance only in the task related to achievement of a positive result, whereas when working in a conflict situation there was no change in reproducibility of results after intake of sodium oxybutyrate. After intake of sydnocarb, there was virtually no change in reproducibility of results in both tasks, as compared to the control. Accuracy of correction of results of operator work with dominance of motivation to reach the goal had a tendency toward decline after intake of fenibut and mebicar. Intake of sodium oxybutyrate elicited some decline of accuracy in correction of results of performance of the first task. This effect of tranquilizers on correction of operator work was less marked when there was conflict between motivation for achievement and avoidance of failure. Sodium oxybutyrate and sydnocarb had virtually no effect on this indicator.

Data on the effects of the agents and placebo on the positions in the zone of uncorrected results are illustrated in Figure 1, which shows that in performing the first test with intake of placebo the range of uncorrected results includes symmetrical positions to the left and right of the target. When performing the task under other conditions, the above zone includes the target and positions to the left of it, which is indicative of a combination of motivation for achievement with marked motivation for avoidance of failure (conflict situation). Moreover, according to the data in Figure 1, the typical feature of the effect of the tested tranquilizers on the overall position composition of the zone of the subjective target for the entire group of subjects is that this zone includes additional positions to the left and right of the target when performing the first task, as well as exclusion or reduction in number of extreme positions to the left of the target when working against a background of conflict motivations (second task). Sodium oxybutyrate did not alter the position composition of the zone of uncorrected results in performing the second task, but narrowed somewhat this zone during performance aimed at

[illegible] Interestingly, sydnocarb in the dosage tested [illegible] composition of the zone of the subjective target [illegible] psychological conflict, which were analogous [illegible] after intake of tranquilizers. The zone of subjectively [illegible] showed virtually no change in performance of the first task [illegible].

[illegible] of tested agents on parameters of operator performance

AGENT AND DOSAGE, G	OBJECT STOPPED EXACTLY ON TARGET			OBJECT STOPPED ON TARGET WITHOUT DEVIATION TO RIGHT (CONFLICT SITUATION)		
	COEFFICIENT OF REPRODUCIBILITY OF RESULTS	COEFFIC. OF ACCURACY OF CORRECTION	SHARE OF EXACT HITS %	COEFF. OF REPRODUCIBIL. OF RESULTS	COEFF. OF ACCURACY OF CORRECT.	SHARE OF EXACT HITS %
PLACEBO	0,284 ± 0,037	0,323 ± 0,024	29,1	0,291 ± 0,027	0,309 ± 0,028	30,4
PHENAZEPAM, 0.001	0,407 ± 0,053*	0,023 ± 0,044*	30,9	0,398 ± 0,043	0,335 ± 0,056	35,8*
FENIBUT, 0.5	0,300 ± 0,020	0,307 ± 0,057	32,8	0,316 ± 0,069	0,331 ± 0,032	28,7
MEBICAR, 0.9	0,324 ± 0,033	0,289 ± 0,024	29,7	0,355 ± 0,30	0,313 ± 0,019	30,3
SODIUM OXYBUTYRATE, 2.0	0,351 ± 0,031	0,258 ± 0,030	28,7	0,291 ± 0,031	0,293 ± 0,041	29,3
SYDNOCARB, 0.01	0,288 ± 0,043	0,327 ± 0,025	30,7	0,230 ± 0,077	0,290 ± 0,022	31,1

[illegible] that differ with statisticaly reliability from the same parameters obtained after intake of placebo (P<0.05).

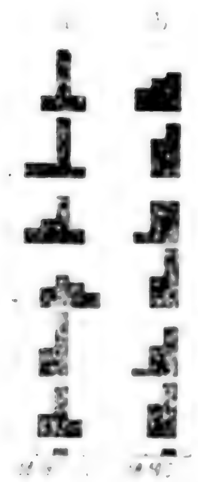

Figure 1.
Effect of tested agents on position composition of zone of uncorrected results

a) object stopped exactly on target
b) object stopped on target without deviation to right (conflict situation)
1) placebo
2) fenibut
3) mebicar
4) phenazepam
5) sodium oxybutyrate
6) sydnocarb

[illegible] that there was insignificant change in results of work [illegible] on both tasks after intake of the tested agents and [illegible]. The absence of appreciable differences in results [illegible] first and second tasks in this series of experiments with [illegible] might be attributed to the duration of the entire test [illegible], as a result of which subjective perception of the competitive [illegible]. However, the intensity of motivation was sufficient [illegible] test period to achieve high results.

Table 2. Effect of change in level of motivation on parameters of operator performance

LEVEL OF MOTIVATION	OBJECT STOPPED ON TARGET			OBJECT STOPPED ON TARGET WITHOUT DEVIATION TO RIGHT (CONFLICT SITUATION)		
	COEFFICIENT OF REPRODUCIBILITY OF RESULTS	COEFFICIENT OF ACCURACY OF CORRECTIONS	SHARE OF EXACT HITS ON TARGET %	COEFFICIENT OF REPRODUCIBILITY OF RESULTS	COEFFICIENT OF ACCURACY OF CORRECTIONS	SHARE OF EXACT HITS ON TARGET %
LOW	0,164 ± 0,039	0,182 ± 0,015	13,4	0,190 ± 0,037	0,193 ± 0,019	14[illegible]
HIGH	0,280 ± 0,035*	0,219 ± 0,026	24,0*	0,314 ± 0,034*	0,222 ± 0,08[illegible]	[illegible]

*Values differ with statistical reliability from the same parameters of performance with low motivation ($P<0.05$).

It was deemed desirable to compare the obtained data on effects of the tested psychotropic agents on parameters of operator performance related to the subjects' subjective attitude toward achieving an objectively set goal to the results obtained with change in level of motivation in performing the given tasks. The results are listed in Table 2 and Figure 2. According to the data in Table 2, increased motivation for performance of both tasks led to increase in results of work. There was a distinct disproportion between the increase in results of work when performing the first and second tasks. The results of work against a background of high motivation were substantially lower in performing the second task than the first, which is indicative of the negative effect of the simulated psychological conflict on results of this form of sensorimotor activity. The substantial decline of results of performance against the background of high motivation when changing from the first to the second task could be attributable to the distinct perception by the subjects of the competitive situation and increased subjective importance of the material reward that was given, in this instance, immediately after termination of the test. The effect of training [conditioning] is ruled out here, since the data listed in Table 1 about the results of work after verbal instructions had been repeated with stability for several days prior to the experiment. Against a background of high motivation, we observed a rise of the coefficient of reproducibility of results with insignificant changes in coefficient of accuracy of correction of results. Activit

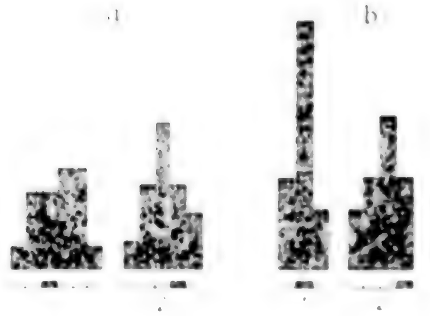

Figure 2.
Change in position composition of mean of unaffected results with different levels of motivation.
X-axis shows # position
a) low motivation
b) high motivation
1) object stopped exactly on target
2) object stopped on target without deviation to right (conflict situation)

[illegible] was also [illegible] positive target. [illegible] the zone of uncorrected results narrowed when performing both tasks. [illegible] of positions to the right of the target for the second [illegible] in the pharmacological part of our study with [illegible] (Figures 1 and 2).

[illegible] this series of studies to the effects of tran- [illegible] the nature and tactics of operator work, we observed similar [illegible] of the zone of uncorrected results after intake [illegible], as well as with diminished motivation for performance of [illegible]. Perhaps, the decrease in strictness of subjective criteria of [illegible] after intake of tranquilizers is related to diminished motivation [illegible]. It can be assumed that the observed narrowing (exclusion of [illegible] of the zone of uncorrected results when working [illegible] conflict is related to diminished motivation [illegible] failure, which leads to increase in risk taken by subjects [illegible] the second task. The diminished motivation for achievement [illegible] of results already achieved, on the one [illegible] correction of activity aimed at achievement of a positive [illegible]. The increased degree of risk taking after intake [illegible], phenazepam, could be the basis of its positive effect on [illegible] conflict. It is then [illegible] phenazepam depresses motivation for avoidance to a [illegible] motivation for achievement. The analogous effect of fenibut [illegible] is considerably weaker and manifested when these agents [illegible] tested doses only in the form of typical changes in the zone [illegible] results. This indicates that expressly the motivation elements [illegible] are the most sensitive to tranquilizers. Most probably, this [illegible] linked with their specific action. It is interesting to [illegible] that intake of sydnocarb also increased the degree of risk-taking in a [illegible]. Sodium oxybutyrate did not alter the degree of motivation [illegible] success and avoidance of failure; it did not increase the [illegible] risk-taking, and this conforms to data concerning its mild tranquilizing [illegible] sedative properties [13]. On the basis of our [illegible], it can be concluded that it would be promising to study phenazepam [illegible], perhaps, the entire group of tranquilizers in optimum doses) as agents [illegible] the types of operator work that are performed in situations [illegible] conflict, where achievement of the end result is related to [illegible] to avoid the effect of a threatening factor, which [illegible] types of operator work in the [illegible] field.

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UDC: 629.78:574.685]:595.77]-15

OPTIMIZATION OF PROCESS OF STORING HOUSEFLY PUPAE FOR UTILIZATION OF ORGANIC WASTE IN BIOLOGICAL LIFE-SUPPORT SYSTEM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 2 Aug 82) pp 63-65

[Article by Ye. G. Golubeva and V. V. Nosov]

[English abstract from source] The method of experiment orthogonal planning was used to study the combined effect of three factors (ambient temperature, humidity, and storage time) on the yield characteristics of the storage of Musca domestica L. pupae as utilizers of organic wastes in the biological life support system. The application of the type 2^{3-1} fractional factorial experiment with the generating ratio $x_3 = x_2 x_1$ and analysis of the resultant regression equation showed that the pupal viability tended to grow as the temperature increased and the time storage and humidity decreased. Step-by-step optimization according to Box-Wilson gave the following optimal conditions for pupal storage (without viability losses): ambient temperature +16°C, relative humidity 37-39%, and storage time 15 days.

[Text] Inclusion of some organism in a biological life-support system (BLSS) as an element of some part of it involves investigation of a wide range of problems pertaining to both the biology of the species and biotechnical distinctions of its upkeep and use in this system.

The possibility of creating a reserve of a culture of the species is an important factor in its biology in order to restore the process of cultivating an organism, which could be disrupted under the effect of various extreme factors.

For the Musca domestica L. housefly, which is one of the promising species of insects for utilization of organic waste in BLSS [1], to create a reserve of culture it is desirable to use the active stages of its life cycle (egg, pupa).

Our objective here was to find optimum conditions for storage of housefly pupae (without loss of viability) in connection with evaluation of the possibility of creating a supply of cultures of this organism when it is used in the mineralization element of BLSS.

... given problem, we selected the strategy of step-by-step optimization using the method of Box-Wilson [2]. According to this method, to determine the direction of movement toward the extremum we followed a plan of the DFE [photoelectric densitometer] 2^{3-1} type with generation of equation $X_3 = X_2X_1$, and obtained a mathematical description of the process in the tested range of experimentation in the form of a first-order polynomial. Coefficients of the polynomial were calculated using the least-squares method and the following formula [2]:

$$\bar{a} = (F'F)^{-1}F'Y, \tag{1}$$

where F is the matrix of independent variables, $\bar{a} = (\hat{a}_0, \hat{a}_1, \hat{a}_2, \hat{a}_3)$ is the vector of estimates of regression coefficients, Y is the matrix of observations and ' is the sign of transposition.

The obtained estimates of regression coefficients are coordinates of the gradient in whose direction there was step-by-step movement toward the extremum. The spacing of steps (in natural units) for the tested factors when moving over a gradient was determined by the following formula [2]:

$$\delta_i = \delta_k \lambda_i |a_i| / (\lambda_k |a_k|), \tag{2}$$

where δ_k is the size of the step chosen to equal 0.5 interval of variation of factor X_k, which had the strongest influence on the output variable; λ_i and λ_k are intervals [ranges] of variation of factors X_i and X_k, respectively; $|a_i|$ and $|a_k|$ are absolute values of estimates of coefficients of regression.

We selected the following on the basis of data in the literature [3, 4], as factors to which the pupae were exposed concurrently: X_1--air temperature (°C), X_2--relative humidity (%) and X_3--pupa storage time at given temperature and humidity (in days). Table 1 lists the conditions for coding the factors and variation intervals.

Table 1.
Factor coding conditions and range of their variation in studies of process of storage of housefly pupae

FACTOR	FACTOR CODING CONDITIONS		
	BOTTOM LEVEL	TOP LEVEL	VARIATION INTERVALS
[illegible]	[illegible]	12 [illegible]	4 C
[illegible]	[illegible]	[illegible]	12%
[illegible]	[illegible] DAYS	21 DAYS	3½ DAYS

The output parameter Y--viability of pupae--recorded in the experiments was determined as the quantity of flies hatched from them (%) in relation to the initial number of pupae. We tested the effect of the above factors on viability of day-old pupae, i.e., in which no more than 24 h had elapsed from pupation time. We conducted a control experiment for each batch of pupae, to determine the rate of fly hatching under insectarium conditions at +25°C and relative humidity of 50-60%. We used in the experiments pupae that developed on human excreta, with a weight of about

[illegible] experiments, the pupae were placed in [illegible] conditions. [illegible] provided by means of [illegible] salt solutions [illegible]. After [illegible], the desiccators were [illegible]. [illegible] from the desiccator, the pupae were kept under [illegible] conditions.

[illegible] and Discussion

[illegible] the matrix for planning and experimental results. After processing [illegible] of the experiments using formula (1), we obtained the following regression equation:

$$\hat{Y} = 28.0 + 28.0x_1 \; 0.9x_2 - 0.9x_3 \qquad (3)$$

[illegible] from this equation that factor X_1 had the strongest effect on $\hat{Y}$ while [illegible] of factors X_2 and X_3 were the same and appreciably smaller. This [illegible] that, for day-old pupae, ambient temperature is the most important [illegible] determining their viability.

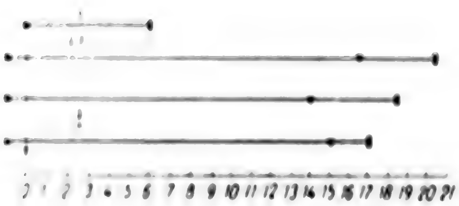
Table [illegible]. Matrix for planning and results of experiments with optimization of the [illegible] of storing housefly pupae

Experiment No.	Factors			Results			
	X_1	X_2	X_3	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	−1		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	−1		41	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	−1		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	−1		[illegible]	[illegible]	
Basic level	[illegible]	[illegible]	[illegible]				
Variation interval							
[illegible]	4	[illegible]	[illegible]				
	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	2	[illegible]				

[illegible] the [illegible] of the effect of the tested factors on the output parameter, we [illegible] a tendency toward increase in pupa viability with elevation of ambient temperature (the coefficient with X_1 has a "+" sign), decrease in [illegible] and duration of pupa storage (the coefficients with X_2 and X_3 have [illegible] sign).

[illegible] of the tested factors [illegible] with the model of [illegible] is consistent with data in the literature concerning the [illegible] of different factors on viability of housefly pupae [3, 4].

[illegible] in the direction of steep ascent, which was done using [illegible], is illustrated in Table 2. Of the planned experiments, we [illegible] and 7; experiments Nos. 1 and 3 were done "mentally," [illegible], without running them.



Duration of development of housefly pupae when stored under different conditions. Dark circles show pupation time; triangles show time when pupae were placed in insectarium; rectangles show time that flies hatch from pupae. The arrow shows start of experiment.

a) control group

b–d) experiments Nos 5, 1 and 8, respectively

1. Viability of pupae in control material did not exceed 90% in experiments Nos 1-4 and 95.5% in Nos 5-9 (see Table 3); for this reason, the viability levels calculated with the model, which were close to control levels, should be considered the maximum that is possible.

2. Some temperatures prevent long-time storage of pupae. Thus, according to data in the literature [3], a temperature of +20°C retards development of day-old pupae by no more than 2 days. For this reason, movement over the gradient in the direction of the extremum is inexpedient in the temperature range of +20°C and higher.

In the course of the experiment, we also recorded the period between transfer of pupae from experimental to insectarium conditions to the moment that flies were hatched from them. This period is part of the total time of pupa development. In the control group of pupae, this was the time from the moment of pupation to the start of hatching. In the experimental group, the period of pupal development consisted of three periods: period from the moment of pupation to placement in experimental conditions; period of exposure to the tested factors and the above-mentioned period between time of transfer of pupae from experimental to insectarium conditions to the start of hatching of flies.

Table 3. Experiment planning in the direction of "steep ascent" (on the basis of results in Table 2)

EXPERIMENT NO	FACTORS				EXPERIMENTAL RESULTS		
	X_1	X_2	X_3	$\hat{Y}$	$Y^{(1)}$	$Y^{(2)}$	$\bar{Y}$
5	10	45	16,5	46,5	46,0	52,5	49,3
6	12	43	16,0	64,1			
7	14	41	15,5	81,8	88,9	100,0	94,5
8	16	39	15,0	99,4	95,0	97,0	96,0
9	18	37	14,5	117,0			

Note: Here and in Table 2: $\hat{Y}$ is the value of the output parameter calculated from model (1); $Y^{(1)}$ and $Y^{(2)}$ are repeats of the experiment, with 100 pupae in each; $\bar{Y}$ is the mean value in the experiment. Average viability of pupae in control material constituted 90% in experiments Nos 1-4 and 95.5% in experiments Nos 5-9.

The Figure illustrates duration of pupal development in the control group and in experiments Nos 1, 5 and 8. Combined analysis of the figure and Table 3 shows that maximum duration of development (20 days) was observed at +10°C (experiment No 5), when hatching was delayed by 14 days, as compared to the

control; however, under these storage conditions, viability of pupae dropped from 96% (control) to 49%.

It should be noted that raising the temperature from 10 to 12°C (experiments Nos [illegible] and 1) had little effect on duration of development, but raised viability to [illegible]. The temperature range of 10-12°C is apparently critical to survival of day-old pupae when they are exposed to such temperatures for a long period of time.

At +16°C (experiment No 8), when hatching was delayed by 12 days, viability of pupae did not diminish, as compared to viability in control material.

For this reason, there are grounds to recommend the following upkeep conditions for storage of day-old pupae: ambient temperature +16°C, relative humidity 37-39% and storage time 15 days.

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METHODS

UDC: 629.78:612.014.482.5

ESTIMATES OF COSMIC RADIATION DOSES IN NEAR-EARTH ORBITS WITH APOGEE UP TO 1000 KM DURING PERIOD OF SOLAR INACTIVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 2 Jun 82) pp 66-67

[Article by L. N. Smirennyy and A. V. Khortsev]

[Text] At the present time, best explored in manned spaceflights are orbits with apogees up to 500 km in altitude. The flights of the Soviet craft, Vostok, Voskhod, Soyuz, American Mercury, Gemini, Apollo and manned stations, Salyut and Skylab, followed such courses. For this reason, development of methods that would permit rapid assessment of the radiation situation in orbits at altitudes of up to 1000 km is of considerable interest with regard to planning the safety of spacecraft and station crews.

The radiation situation on courses at altitudes of up to 1000 km with quiescent [inactive] sun is determined by galactic cosmic radiation (GCR) and radiation from earth's radiation belts (ERB), which descend to 200-300 km in the region of the Brazilian anomaly.

A detailed calculation of doses in near-earth orbits requires determination of flux and spectra of GCR and ERB at different points of the trajectory, followed by addition of these data for the entire flight course. However, the spatial and energy distributions of cosmic radiation at altitudes of up to 1000 km have not yet been studied sufficiently; moreover, performance of relevant full-scale calculations is a rather time-consuming process, even for modern computers. At the same time, when planning spaceflights and choosing optimum conditions for them, it is necessary to consider a large number of variants of trajectories and assemblies of space vehicles. In order to assess the radiation situation at altitudes of up to 1000 km, we can propose a rather simple method of estimating cosmic radiation doses when the sun is inactive. This method is based on experimental data about doses, which were obtained during flights of artificial earth satellites and the results of measurement of attenuation of cosmic radiation dosage by shielding materials.

Attenuation of cosmic radiation dose in an orbit with apogee up to 906 km in altitude was measured during the flight of Cosmos-110 satellite. The obtained dosage as a function of shielding thickness can be approximated with the following equation with a 10-15% margin of error:

$$K_\Delta = 1.02 \exp(-0.32\delta) + 27 \exp(-0.029\delta). \qquad (1)$$

This equation conforms well to the attenuation curve previously obtained [1] for protons in earth's radiation belt and can be used in the case where these protons are responsible for most of the dose. With decrease in altitude of apogee, there will be increase in contribution to the dose of high-energy GCR particles and, accordingly, the related margin of error with an apogee of 200 km and shielding thickness of 15 g/cm^2 could constitute about 50%.

As the basic equation for estimating doses in circular orbits at altitudes in the range of 200-1000 km, one can use the one based on the results of measurements taken in the United States on the OVI-4 satellite [2]:

$$D = A\left(\frac{H}{100} - 2\right)^B \text{ rad/day} \qquad (2)$$

where H is the altitude of orbit (in km), A and B are coefficients that depend on the angle of inclination of the orbital plane. Since determination was made of distribution of surrounding thicknesses $\delta(\omega)$ for the radiation detector aboard OVI-4, assuming that the composition of radiation is constant at the point under study and using formula (1), let us turn from expression (2) to the one that describes dosage as a function of shielding thickness:

$$D(\delta) = A\left(\frac{H}{100} - 2\right)^B \frac{K_\Delta t}{\frac{1}{4\pi}\sum_{i=1}^{n} K(\delta_i)\,\omega_i} \text{ rad} \qquad (3)$$

where δ is thickness of aluminum shielding (g/cm^2), t is flight duration (days). The values of coefficients A and B were found on the basis of data in [2] and results of measurements taken aboard Cosmos-110. These coefficients as a function of angle of inclination of orbital plane can be written down in the following forms:

$$\begin{aligned} A &= 0.024 + 7\cdot 10^{-3}\cos i \\ B &= 2.15 - 4.16\cdot 10^{-3} i. \end{aligned} \qquad (4)$$

Substituting in (3) the values of A and B, as well as data on the distribution of thicknesses of the detector obtained from the OVI-4 satellite, we shall obtain the expression for calculating the dosage in a circular orbit with angle of inclination i and altitude H:

$$D = A\left(\frac{H}{100} - 2\right)^B \cdot [1.5 \exp(-0.325\delta) + 0.4 \exp(-0.029\delta)]\, t. \qquad (5)$$

In the case of long-term flights, when the apogee makes a revolution of 2π or more as a result of "drift," the dosage in elliptical orbits can be calculated

on the basis of data about doses in circular orbits with consideration of the time spent by the satellite at the corresponding altitude. The doses at altitude H can be determined using the following expression:

$$D(H, i)\, dt(H) \tag{6}$$

where $D(H, i)$ is mean dose rate in circular orbit at altitude H and with angle i of inclination of orbital plane; $dt(H)$ is the time spent at altitude H when flying in a specified orbit. Expression (6) can be written down as follows:

$$D(H, i)\, \frac{dt(H)}{dH}\, dH \tag{7}$$

then the dosage during a flight over a trajectory with apogee altitude of H_a, perigee of H_n and angle i of orbital inclination can be calculated by integration of (6):

$$D(H_n, H_a, i) = 2\int_{H_n}^{H_a} D(H, i)\frac{dt}{dH}(H)\, dH. \tag{8}$$

One can use the above expression(5) as $(D(H, i)$.

The altitude of the satellite at any point of the orbit is expressed as an eccentric anomaly:

$$H(E) = a(1 - e\cos E) - R_3. \tag{9}$$

For elliptical orbits with H_n>200 km and H_a<1000 km, the highest value of eccentricity is 0.06. We can thus express the eccentric anomaly with a margin of error of over 6% as the time in the simple formula:

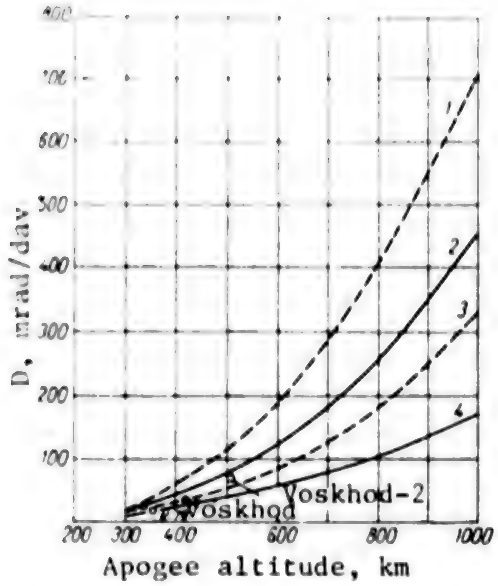
$$E = \mu t \tag{10}$$

Thus, the altitude of the satellite as a function of time can be expressed in the following form:

$$H(t) = a(1 - e\cos \mu t) - R_3, \tag{11}$$

where $\mu = \sqrt{\frac{K}{a^3}}$ is mean angular velocity (radian/s), $K = 3.9853 \cdot 10^5$ км^{3}s^{-2}.

From expression (11) we obtain:



Dose rate as a function of apogee height for elliptical orbit with 65° angle of inclination of orbital plane and perigee of 200 km. White circle refers to experimental point of Voskhod-2 craft and black one to Voskhod; square refers to K-79
1-4) shielding thicknesses of 1, 3, 5 and 10 g/cm^2, respectively

$$\frac{dt}{dH} = \frac{1}{\mu\sqrt{1-\left(\frac{a-H-R_3}{ae}\right)^2}\, 8{,}64\cdot 10^4\, ae} \text{ (days/km)} \quad (12)$$

Substituting expressions (5) and (12) in formula (8), we shall obtain dosage as a function of parameters of elliptical orbit and flight duration:

$$D(H_a, H_n, i, t) = [1{,}5\exp(-0{,}325\delta) + 0{,}4\exp(-0{,}0291\delta)] \times \frac{2t(2{,}43 10^{-2} - 7{,}04 10^{-3}\cos i)}{8{,}64 10^4 ae\mu} \times \int_{H_n}^{H_a} \frac{\left(\frac{H}{100}-2\right)^{2{,}15 - 4{,}16 10^{-3} i}}{\sqrt{1-\left(\frac{a-H-R_3}{ae}\right)^2}}\, dH. \quad (13)$$

The obtained expression was used to calculate doses for circular and elliptical orbits under shielding of 1-10 $g\cdot cm^{-2}$ (see Figure). This figure also illustrates the results of dose measurements taken during orbital flights of spacecraft and artificial earth satellites. Unfortunately, in most cases there are no data about the shielding of radiation detectors by structural elements and equipment, which makes it difficult to draw a detailed comparison of estimated and experimental values. The average thickness of materials that shield radiation detectors aboard spacecraft and satellites changes, as shown by estimates, in the range of 3-5 $g\cdot cm^{-2}$. Under this condition, there is quite satisfactory agreement of estimated and experimental data. This warrants the belief that it is warranted to use the proposed method for assessing the radiation hazard of orbital flights at altitudes of 200 to 1000 km.

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EXPEDIENCY OF USING PERSONAL DOSIMETERS FOR EFFECTIVE DOSES DURING MANNED SPACEFLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 14 May 82) pp 68-69

[Article by I. V. Bochvar, T. I. Gimadova and I. B. Keirim-Markus]

[Text] In spaceflights to other planets, when cosmonauts may be repeatedly exposed to the radiation from solar flares and irradiation levels could be significant, it is necessary to determine the effective dose received by each crew member. Apparently, it would be desirable to do this operationally, in order to make the decision as to feasibility of continuing with the flight or taking steps to protect the health of cosmonauts.

For this purpose, one can use onboard equipment, which processes information about dose rates in accordance with a specified program; however, it does not provide the required true levels of effective doses for each crew member. When using the sensors that are attached to specific points, the onboard equipment will not take into consideration such factors as the actual movement of cosmonauts in the craft, their extravehicular activity, conditions of servicing the nuclear power plants of the craft, etc. All of the foregoing is indicative of the fact that the crews of spacecraft should be provided personal dosimeters, which measure effective doses. Thermoluminescent aluminum phosphate glass of a special composition [1] is used as the dosimeter detector. The glass plate is disk-shaped, with a diameter of 8×1 mm.

The feasibility of using detectors of the recommended composition to measure effective doses is due to the fact that a decline of its readings as time passes corresponds approximately to the law of change in effective dose as a function of time (Figure 1). Consequently, the readings of a dosimeter with such a detector would correspond to effective doses at any point in time after the start of irradiation.

Since the decline of readings of the ED-1 dosimeter reproduces inaccurately, as evident from Figure 1, the course of effective dosage as a function of time, there is an additional error factor in determing effective doses. Figure 2 illustrates this error factor as a function of time, during which the dosimeter is used, for two extreme cases: single exposure to radiation that occurs at the start of using the dosimeter--maximum additional error, and for uniform irradiation throughout the period of its use. In the case of using the

or greater for 3 months, maximum error constitutes less than 50%. As can be seen in Figure 2, in the case of uniform irradiation, the additional margin of error does not exceed ±20% over a period of about 200 days. In the future, in the event of major solar flares (which could be known from the readings of other equipment), determination of readings on the personal ED-1 dosimeter could be made directly aboard the craft. Then the readings of the ED-1 dosimeter will give objective information about the actual effective dose to crew members at a given point in time.

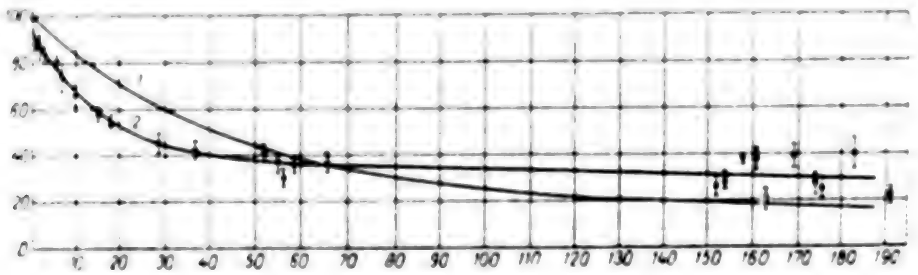

Figure 1. Changes in effective dose and ED-1 dosimeter readings as a function of time. Y-axis, total light [light yield] from RTL [radio equipment lamps?] (%)

1) effective dosage according to Blair-Davidson theory (f = 0.15, β = 0.022 day^{-1} [2]
2) ED-1 dosimeter readings at 33-34°C temperature

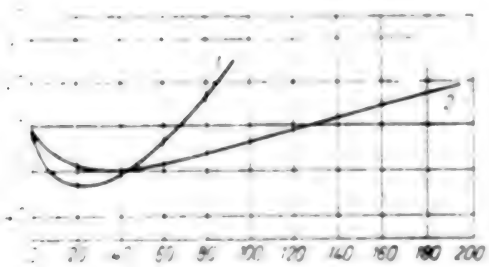

Figure 2.
Additional error in determination of effective dose with ED-1 dosimeter when using laboratory measurement equipment. Y-axis, tissue dose under shielding with thickness of 1 g•cm^{-2}, rad
1) single exposure to radiation at start of using dosimeter
2) uniform irradiation throughout period of dosimeter use

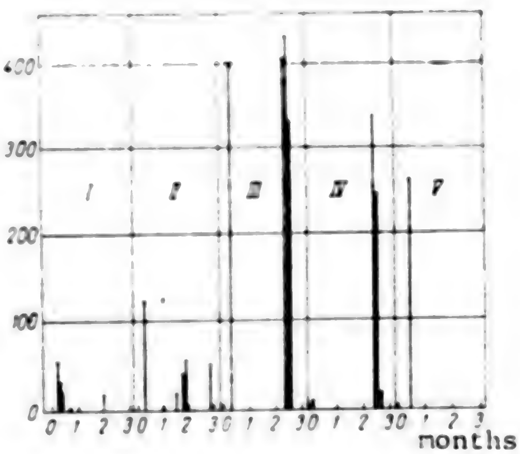

Figure 3.
Distribution of tissue dose from solar flares as a function of time
I-V) variants

As an example, the Table lists the results of estimating effective dosage (see Figure 1, curve 1) for several solar flares which actually occurred in

1957-1969, as well as determination of effective dose according to readings on ED-1 dosimeter (see Figure 1, curve 2), total dose and doses determined from readings on personal monitoring dosimeter using glass (IKS), and the corresponding margins of error. It was considered that the dosimeters were used for 3 months. The tissue doses from solar flares were taken for shielding with thickness of 1 g/cm^2. In calculating the effective dose, the following values of parameters were used in the formula: $f = 0.15$ and $\beta = 0.022$ day^{-1} [2]. Figure 3 illustrates distribution of tissue dose from solar flares over the period of dosimeter use.

Results of estimating effective dose as determined from readings of different dosimeters

VARIANT	TIME OF ASSUMED USE OF DOSIMETER	D_{EFF}, RAD	D, RAD	READING ON IKS DOSIM. WITHOUT CORRECTION FOR DECLINE RAD	READING ON EFFECTIVE DOSE DOSIMETER, RAD	MARGIN OF ERROR IN DETERMINATION OF EFFECTIVE DOSE, %		
						WITH IKS	IKS WITHOUT CORREC. FOR DECLINE	EFFECT. DOSE DOSIMETER
I	20/VIII 1957 19/XI 1957	42,1	127,3	106	46,0	+202	+152	+9,2
II	1/VII—30/IX 1958	143,8	297,3	247	135,6	+107	+72	—5,7
III	1/V—30/VII 1959	989,5	1561	1297	816,5	+58	+31	—17,5
IV	1/IX—30/XI 1960	452,9	608,5	505	347,9	+34	+12	—23,2
V	17/X 1969 16/I 1970	81	262	218	94,4	+224	+170	+16,3

Accoridng to the table, in the first place, the effective dose is substantially lower (one-half--one-third) than the cumulative dose for the same period of time; in the second place, use of the ED-1 dosimeter makes it possible to determine effective dosage with the error of margin that is acceptable to practice. Figure 3 and the Table show that with appearance of a series of flares within the period of dosimeter use, there is appreciable decline of error factor in determination of effective dose. At the same time, use of a cumulative dose dosimeter does not permit consideration of actual distribution of dose in time and, consequently, this traditional personal dosimeter is not suitable for determining the hazard during long-term spaceflights in interplanetary space in the presence of high radiation doses.

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EARLY DETERMINATION OF PARAMETERS OF PROTON FLUX FROM SOLAR FLARES ON THE BASIS OF RADIO-BURST DATA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 14 May 82) pp 69-72

[Article by S. T. Akin'yan, V. V. Fomichev and I. M. Chertok]

[Text] In addition to prediction of solar activity, quantitative identification of proton flares is acquiring increasing scientific and practical significance. Such identification consists of determining, on the basis of observations of a burst that is already occurring, whether this flare will be associated with appreciable increase in proton flux [for example, with intensity J(E>10 MeV)≥ 1-5 cm^{-2} s^{-1} av^{-1}], as well as to estimate the expected parameters of proton flux in near-earth space (maximum intensity, time parameters, indicator of energy spectrum). Quantitative determination can be made from tens of minutes to tens of hours in advance, and it should be an element of the system of operational provisions for radiation safety in space.

Among the different types of electromagnetic radiation associated with a flare, radio waves are the most suitable for forecasting purposes. They are notable for the fact that they are easy and accessible to observation. Moreover, it is of basic importance that emission at different radiofrequencies is generated at different altitudes in the sun's atmosphere. Microwave bursts, which occur in the chromosphere and lower corona, make it possible to assess the effectiveness of acceleration of particles in the flare and their energy spectrum. Bursts in the meter and decameter ranges, generation of which occurs in the corona, also carry information about the exit of particles into interplanetary space.

We describe briefly below the main theses of the method of quantitative identification of proton flares according to radio bursts, which was developed at the Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation of the USSR Academy of Sciences [1]. The method is based on the results of statistical analysis of patterns characterizing the link between parameters of flux of protons with energy E>10, 30 and 60 MeV, which are observed in near-earth space, after a specific flare on the solar disk,and parameters of corresponding radio bursts in the centimeter and meter ranges. Such analysis was performed in [2, 3] on the basis of data about proton events in 1965-1969, and several high-energy phenomena in 1971 and 1972. The method consists of

two main stages: a) determination of proton content of a given flare; b) calculation of expected parameters of proton flux near earth in cases where the flare was identified as containing protons.

Singling out of the numerous flares that occur on the sun those that could be the source of appreciable increase in proton flux, i.e., proton flares, is done on the basis of the so-called yes-no criterion. For phenomena with intensity $J(E>10\ \text{MeV}) \geq 1\text{-}5\ \text{cm}^{-2}\ \text{s}^{-1}\ \text{av}^{-1}$ in earth's orbit, the criterion takes into consideration, in particular, the presence of a rather intensive (hundreds of s.u.; 1 s.u. ["s.yed."] = $10^{-22}\ \text{W m}^{-2}\text{Hz}^{-1}$) and hard (i.e., with spectrum maximum at frequencies $f \geq 5$ GHz), nonpulsed (tens of min) microwave burst [flash?], as well as a substantial meter-range component (hundreds of s.u.), including types II and IV bursts. On the whole, this forms a typical U-shaped frequency spectrum of radio waves (Figure 1).

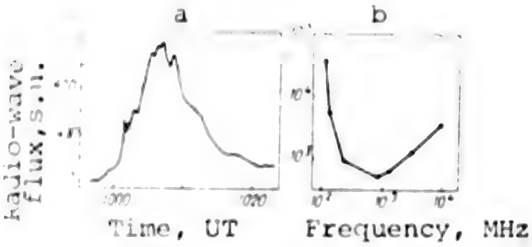

Figure 1.
Microwave burst (a) and frequency spectrum of radio emission (b) typical of proton flares (22 Nov 1977)

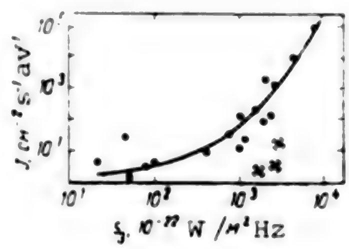

Figure 2.
Intensity of proton flux as a function of radioparameter S_3 for flares in OLI (E>10 MeV)

If the flare satisfies the proton content criterion, one turns to the second stage of identification--calculation of expected parameters of flux of protons with energy E>10, 30 and 60 MeV near earth. The general expression for calculation of maximum intensity of proton flux in each of the energy ranges according to a given initial parameter of a microwave burst x has the following appearance:

$$J = k \cdot \phi_{1,2}(\Theta) \cdot J(x) \qquad (1)$$

Here, $J(x)$ is a support [reference?] function of intensity characterizing the mean intensity of protons for a given base value of parameter x, which can be expected in the segment of earth's orbit corresponding to the optimum longitude interval (OLI) for the flare in question. This function has been defined for several base parameters by means of analysis of proton flares localized in the interval of 20-80°W (OLI for earth), where the effect of heliolongitude is insignificant. The typical appearance of intensity function is illustrated in Figure 2. One can use as the base parameter data about microwave bursts at frequences $f \sim 3$ and 9 GHz: maximum intensity $S_{3,9}$, integral flux of build-up phase $R_{3,9}$ and total flux of burst $P_{3,9}$.

In equation (1), $\delta_{1,2}(\Theta)$ is a function of longitudinal attenuation for phenomena with intensive--index 1 (flux density at $f \leq 245$ MHz $S \geq 5000$ s.u.; types II, IV bursts with score of ≥ 3) and weak--index 2 ($S < 5000$ s.u.; types II and IV bursts with score of ≤ 2) meter component (Figure 3). It permits evaluation of intensity of proton flux directly near earth, with consideration of heliolongitude of flare Θ and information about conditions of particle exit into interplanetary space, which is contained in the intensity of the meter component. This function reflects, in particular, the following effects: a) within the limits of OLI, phenomena with intensive meter component (favorable conditions for particle exit); b) beyond the OLI, on the eastern half of the disk there is noticeable attenutation of proton flux recorded near earth, and with increase in east longitude of the flare the attenuation effect increases by tens and hundreds of times; c) on the eastern half of the disk the conditions of particle exit are such that the flux of protons from flares, which are associated with intensive meter radio waves, undergoes considerably greater attenuation than the flux of protons from flares with weak, meter radio waves; d) for phenomena related to flares in the east, the effect of heliolongitudinal attenuation of proton flux is enhanced when there is increase in particle energy. As a result, the energy spectrum of proton flux recorded near earth becomes, on the average, increasingly soft as it comes closer to the eastern limb.

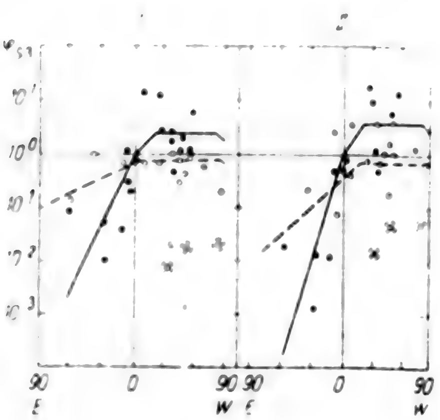

Figure 3.
Coefficient of attenuation as a function of heliographic longitude Θ for phenomena with intensive (black symbols, solid line) and weak (white symbols, dash line) meter component of radio waves
I) E>10 MeV II) E>30 MeV

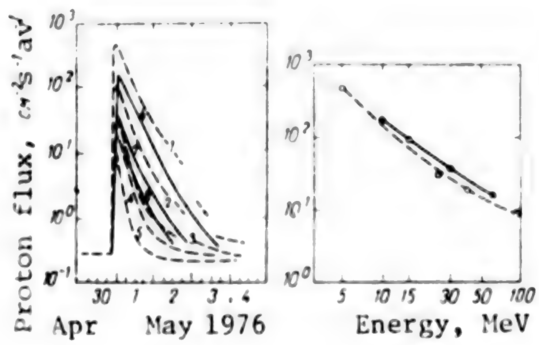

Figure 4.
Example of comparing estimated (solid lines) time profiles (a) and energy spectrum of proton flux (b) to observations (dash line)
1-5) E>5, 15, 26, 40, 90 MeV
6-8) E>10, 30, 60 MeV

Spectral correcting coefficient k in equation (1) is used to take into consideration the effect that reflects the link between frequency spectrum of microwave bursts and energy spectrum of proton flux, and it consists of the fact that phenomena with a soft spectrum of radio waves, in which the maximum of the U-shaped spectrum in the centimeter range is located at frequencies $f_{max} < 8.8$ GHz, are also characterized by the softest proton energy spectrum.

The corresponding reference functions were also determined for the time parameters of proton flux: delays in start of build-up of particle flux near earth from flare Δt_1 and occurence of maximum flux intensity Δt_2 in relation to time [illegible] microwave burst, as well as constant of exponential damping τ. As shown by analysis, all of these parameters are determined primarily by the heliolongitude of flare ϕ: within the limits of the western half of the disk, they do not depend on ϕ, whereas on the eastern half of the disk they increase as the distance increases from the central meridian. Moreover, proton flux from western flares with the most unfavorable conditions for particle exit, in which a high-energy microwave burst is combined with a weak meter component, is characterized by maximum time lag of Δt_1 and Δt_2.

Thus, on the basis of the radio-wave data at a time that is close to the flare maximum one can determine the expected maximum intensity and time parameters of proton flux with energy of E>10, 30 and 60 MeV near earth. This makes it possible to calculate in advance ["in good time"] the time profile of proton flux and evaluate the parameter of particle energy spectrum γ. According to [4], the last-mentioned parameter can also be directly determined (i.e., without preliminary calculation of proton intensity for E>10, 30 and 60 MeV) in relation to maximum intensity at frequencies of 9 and 15.4 GHz at an arbitrary heliographic longitude of a flare.

An important stage in developing the method of quantitative identification of proton flares was to check it out on sizable independent material: data about radio bursts and proton flux in 1970-1977 [5], as well as 1978 [6] and 1979 [7]. It is important this check was made following a plan that simulated a real situation. A comparison of observed and calculated proton flux according to radio-wave parameters revealed that on the whole the check yielded positive results.

Thus, a test estimate for 1970-1977 revealed that the coefficient of correlation between estimated J_e and observed J_o intensity of proton flux for E>10 MeV constitutes $r\sim0.85$. In all energy ranges, the difference between J_o and J_e did not exceed a factor of 2 in 75-85% of the proton phenomena or a factor of 2.5 in 80-90% of the phenomena. Further, the coefficient of correlation between estimated and observed values of the most important time parameter for E>10 MeV constituted $r\sim0.96$, and in 60% of the events on the western half of the disk the estimated and observed values of Δt_2 differed by no more than 2 h, with mean lag of 4 and 8 h for phenomena with favorable and unfavorable conditions for particle exit, respectively. On the eastern half of the disk, the range of scatter is broader, but Δt_2 also increases, reaching 70-80 h near the limb.

On the whole, the general nature of estimated time profiles of proton flux was also close to the observed pattern in most cases. Figure 4 illustrates an example of comparing such profiles, as well as energy spectra at flux maximum.

As for the validity of the criterion of proton content of flares, according to the results for 1970-1977, a forecast of "yes," i.e., of a proton flare was justified with probability P~80%, while a "no" forecast, i.e., about nonproton nature of flares was justified (with a certain restriction at the

[illegible] intensity of the radio bursts in question) with a probability of [illegible]. It is important to note that, in most cases, misses and false alarms [illegible] events characterized by relatively weak particle intensity [[illegible] 10 MeV) < 20-40 cm^{-2} s^{-1} av^{-1}], soft energy spectrum and, consequently, [illegible] not present any special danger.

Our examination of the basic ensemble of phenomena (1965-1969) and results of checks in 1970-1979 indicate that radio bursts can be well-used for quantitative identification of proton flares. It is then possible to take into consideration the heliolongitude of a flare, conditions of particle exit from the region of the flare and energy spectrum of protons. On the basis of data about radio bursts one can single out with sufficient certainty, using a specific criterion, the flares that should be identified as proton flares and then, according to known support [reference] functions, calculate operationally the expected parameters of flux of protons with energy in the range of tens of mega-electron-volts in near-earth space. The positive results of check-out estimations are indicative of stability of the main patterns, upon which the proposed method is based, as well as feasibility of practical use thereof for quantitative identification of proton flares.

It should be stressed that establishment of an operational and around-the-clock service concerned with solar radio-wave emission over a wide range of frequencies is a mandatory prerequisite for practical execution of any method for quantitative identification of proton flares.

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CLASSIFICATION OF REGIONS OF SOLAR ACTIVITY BASED ON METHODS OF PATTERN RECOGNITION THEORY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 14 May 82) pp 72-74

[Article by S. I. Avdyushin, B. O. Berlyand, P. B. Bernshteyn and V. A. Burov]

[Text] Among the problems of assuring radiation safety of spaceflights, that of forecasting solar flares and their consequences holds a special place. While the dosage from earth's radiation belts and galactic cosmic radiation can change from flight to flight (of same duration) by 2-3 times, the dosage from cosmic solar radiation (CSR) on high orbits could vary from billions to hundreds of thousand rads [1, 2]. Guaranteed protection against radiation from flares would lead to increase in weight of spacecraft (there are strict restrictions on weight of shielding [1]) and, consequently, to an increase in flight cost. Forecasting flares and the nature of their radiation could become an alternative to such a solution to this problem.

It is known that the vast majority of flares occurs in active regions (AR). For this reason, the general task of forecasting could be formulated as forecasting the possible evolution of AR. To date, no models of solar activity contain a system of onset and development of AR, and they do not permit prediction of the moment of a flare, the occurrence of CSR injection.

Aside from the imperfection of models for development of forecasting systems for solar phenomena, one should also take into consideration the existing network of observatoriums and observation stations, which is inadequate, as well as the basic distinctions of heliophysical information [3]. These circumstances served as grounds for development of methods of predicting manifestations of solar activity based on pattern recognition theory. The logical procedure for solving problems of forecasting solar activity is similar to forecasting by the synoptic method, but it is objective and can be fully automated.

The actual execution of the scheme consists of the following: the general forecasting problem is formulated as forecasting the possible evolution of an active region, while forecasting proper is reduced to successive determinations of the class to which an observed AR belongs; classification of regions is made on the basis of solving rules selected by recognition methods, and one can use different sets of base data and different algorithms at each stage of formation of the forecast.

Several problems of forecasting manifestations of solar activity were solved on the basis of the algorithms we developed and programs following this scheme.

To assure radiation safety, flares generating high-energy flux in surrounding space are of the greatest interest. For this reason, the first problem we solved was identification of solar flares associated with injection of flux of protons with energy $E_p>55$ MeV, according to concomitant radiations [4]. The limit of 55 MeV was chosen because the radiation hazard to spacecraft crews, when the orbit passes in earth's magnetosphere, could consist only of flares injecting into space fluxes of protons of about such energy, taking into consideration the actual cut-off hardness and observed spectra of CSR protons [5-7]. Thus, there were two classes of events: the first included flares with injection of protons with energy of $E_0>55$ MeV ("hazardous flare" class), where the flux density exceeded the background level according to readings taken on satellites of the Explorer type, and the second--flares after which the flux density of protons with $E_p>55$ MeV did not exceed the background level (class of "safe [nonhazardous] flares"). As base parameters, we used data from observation of radiation in the radio, optical and x-ray ranges, since expressly these characteristics correspond best to the corpuscular radiation from flares. The problem was solved using the Topol' and Sigma algorithms. The results enable us to draw the following conclusions:

1) Separation of flares into the above classes ("hazardous" and "nonhazardous) can be done quite well ($P=0.80$).
2) The score and brightness of a flare are not informative in this problem.
3) The high recognition quality ($P>0.80$) is obtained only with use of parameters of x-ray burst: values of intensity maximum F and time of its decline D. In other words, the characteristics of x-radiation are the most relevant to identification of hazardous flares.
4) The obtained results are reliable, since algorithms based on different approaches to pattern recognition theory yielded similar results.

Forecasting in this problem was done several hours in advance.

In order to be able to make forecasts of "hazardous flares" even earlier and apply the solving rule for operational forecasting, we solved this problem on the basis of data about AR that is delivered in URSIGRAMM codes. The most important criteria for identification of AR of two classes (class I, where there are flares with injection of high-energy protons and class II, AR that did not generate such flares) were obtained from studies of structure and intensity of their magnetic fields. One can identify AR quite efficiently on the basis of a set of parameter-features. Adequate features of AR of each class were obtained, and it was established that the groups of spots in AR generating "hazardous" flares appear either in the preceding revolution of the sun or beyond the limb (i.e., the minimal time required for an AR to reach the flare stage is at least 10 days).

The results of applying the solving rule to forecast "hazardous" flares are listed in the Table.

Validity of forecasting "hazardous" flares

Observed event	Forecast event		Σ
0	4	7	11
$\bar{0}$	1	49	50
Σ	5	56	61

Key: 0) "hazardous flare"
$\bar{0}$) absence of such flare

One can obtain from this table the most important information about the quality of forecasts: probability of occurrence of an event provided that its forecast was issued--$P(H/\Pi)$,* i.e., justification [validity] and probability of a correct forecast provided the phenomenon will occur: $P(\Pi_1/H_1)$--forewarning. In this problem: $P(H_1/\Pi_1) = 0.80$; $P(H_2/\Pi_2) = 0.88$, $P(\Pi_1/H_1) = 0.31$, $P(\Pi_2/H_2) = 0.92$ [8]. These criteria are the most important to forecast consumers. One needs to know both the probability of occurrence of a hazardous flare $P(H_1/\Pi_1) = 0.8$, and the percentage of correct forecasting of such a flare $P(\Pi_1/H_1) = 36\%$.

In the practice of the radiation situation service, one has to make forecasts over longer terms, up to one solar revolution. For this reason, the problem of predicting "protoncontent" of AR for the period of its entire passage over the disk was solved: a) according to its observations near the eastern limb (~60°E) and b) from data prior to its passage beyond the western limb in the preceding solar revolution [9]. The first class (proton AR) includes AR, in which there had been at least one flare within the forecast period, the proton flux density of which exceeded $10^{-1}cm^{-2}s^{-1}av^{-1}$ for E_p>10 MeV according to measurements aboard extramagnetospheric satellites of the Explorer type. The second class refers to AR, in which there was not a single proton flare. A sample of first and second class objects was formed from material referable to 1967-1976. The problems were solved using parameters obtained with routine programs of the solar service. The results of testing the obtained solving rules in real time (for the 1978 period) were as follows: a) 3 out of 5 proton AR going beyond the eastern limb were correctly identified and 62 out of 65 nonproton AR, i.e., overall justification in the problem constituted $P(H/\Pi) = 0.92$, which corresponds to 0.60 for class I and 0.95 for class II; b) 2 out of 4 proton AR going beyond the western limb were correctly identified as were 53 out of 67 nonproton AR, i.e., overall justification in the problem constituted $P(H/\Pi) = 0.77$, which corresponds to 50% for class I and 79% for class II.

To assure normal operation of onboard equipment, data are also needed about variations in flux of x-radiation. Forecasting solar x-ray flares are of principal interest, since expressly they elicit the most significant changes in flux. For this purpose, it was planned to predict whether there would or would not be any class C or higher flares in a given AR within the next 24 h.

The base material consisted of a table of results of daily observations referable to 20 parameters characterizing an AR in H_α, white light, radio-wave and x-ray ranges of wavelengths in 1977. The problem was solved in several stages using the Topol' algorithm. At the first stage, the quality of the solving rule, obtained in an independent test sample, constituted $R(\alpha)$ - 0.11,

*Translator's note: Russian letters, "H" and "П" probably refer to observed and forecast events, respectively.

which conforms to 89% validity, the parameter constituting 38% for the class ("there will be flares") and 96% for class II. At the second stage of solution, the hierarchy was determined of informativeness of different parameters, so that the least informative input data could subsequently be excluded. It is quite desirable to reduce the list of parameters, if only for the reason that some of them are usually wanting for technical reasons when preparing an operational forecast. After reducing the number of parameters, we obtained a new rule, and it was in a meaningful form.

This rule was tested on independent material referable to 1 August to 30 December 1977 (685 cases) and the following results were obtained: overall validity 92%, with 52% for class I and 96% for class II. Classification of all AR (1366 cases) in 1977 (with the exception of those for which no data were available) yielded the following results: overall validity 94%, 63% for class I and 96% for class II.

In conclusion, it can be stated that the methods of pattern recognition theory make it possible to obtain satisfactory results in solving problems of forecasting the manifestations of solar activity that have a direct effect on the radiation situation in near-earth space.

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SIMULATION OF SPACE FORM OF MOTION SICKNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 23 Jul 82) pp 74-78

[Article by R. R. Galle, A. R. Kotovskaya, G. A. Gusakova, L. N. Gavrilova, N. N. Galle and E. A. Skiba]

[Text] According to current conceptions, weightlessness is viewed as a distinctive habitat, in which there is a mismatch between information about spatial position originating from receptors of the semicircular canals and otolith system when the head is moved. When the mismatch signals are of a particular duration and intensity, motion sickness may develop. Spaceflights have confirmed the relationship of motion sickness to motor activity [1-3]. The distinctive manifestations of the space form of motion sickness and its course are attributable not only to differences in predisposition, but individual differences in motor activity of cosmonauts.

We know of many methods of experimental reproduction of motion sickness, most of which are based on cumulative vestibular factors [4-6]. However, there are substantial differences between them and simulation of actual conditions of vestibular function in flight [7], since the end effect is achieved in tests, but such important conditions as duration of exposure and possibility of working with retention of natural motor activity are not met.

In order to simulate the cosmic form of motion sickness, it has been suggested to use the combination of rotation and hypokinesia during immersion [8]. However, considerable technical difficulties must be overcome to follow this suggestion, in particular, with reference to duration of exposure and retention of adequate freedom of natural movements that provoke motion sickness.

So-called canal disease is a simpler and more promising model [7]; it occurs when man is submitted to slow rotation for a long time. Rotation, like weightlessness, is a habitat, in which natural head movements elicit unusual stimulation of the vestibular system. For this reason, the symptoms and course of motion sickness arising in man during long-time active presence in a rotating system have much in common with the space form of motion sickness [9].

Our objective here was to work out a model of motion sickness with use of long-term rotation for use in studies to assess the efficacy of pharmacological agents to prevent the space form of motion sickness.

Methods

These studies were conducted with subjects rotating in a cabin attached on the console of a centrifuge close to the axis of rotation [10]. Two subjects were in the cabin at the same time, and they were allowed some freedom of active motion and displacement. According to the program of work activity, in addition to the movements that the subjects made while seated in chairs, they changed places three times per hour of rotation. However, the nature of the head movements they made was different, due to the individual differences in the subjects' motor activity, as well as their well-being. Accordingly, there was variation of overall characteristics of vestibular factors, which could make it difficult to conduct a comparative analysis of severity of motion sickness, not only in different subjects, but in the same person at different stages of rotation. In order to standardize the level of vestibular factors, we introduced graded head movements in the structure of this study.

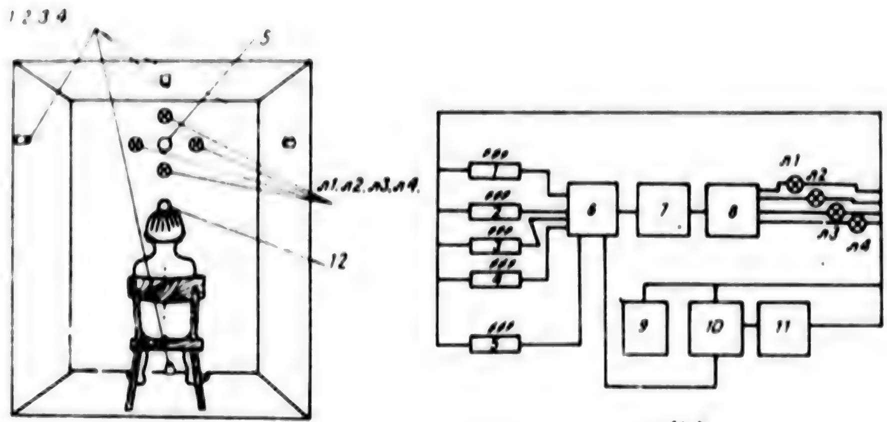
We used three variants of vestibular load tests with active head movements. In the first variant, the subject rapidly tilted his head forward at the rate of 1 tilt per second. In the second variant, the same movements were performed slowly: 1/3 s with 5-s intervals between movements. The third variant involved head movements in different directions (tilt forward back, turns to the right and left, which constituted one cycle of movements) at an arbitrary pace. We used a special device that enabled us to control [graduate] amplitude and consider the number of movements, as well as time spent on performing them. The unit (Figure 1) consists of four photosensors and four lamps indicating the direction of head movements. The four photosensors, placed in appropriate parts of the cabin, react to illumination by a beam from a light source secured on the subject's head; the fifth, central photosensor and the four lamps are in front of the subject. Illumination of the central photosensor turns the lamps on one after the other in random order. Illumination of the other photosensors turns the lamps off. The unit also has a movement counter and chronometer.

In each test, rotation lasted 5 h. This is enough time to perform active movements during slow rotation that would develop the typical syndrome of motion sickness. At the same time, this is not long enough for adaptive reactions to appear [9]. Five-hour exposure also makes it possible to study the duration of the preventive effect of agents against motion sickness [11].

During rotation, we examined the functional state of the cardiovascular and vestibular system, tested physical and mental work capacity, as well as ability to retain equilibrium in erect position.* Special attention was given to analysis of the severity of manifestation of motion sickness, which ultimately determines endurance of rotation and work capacity under these conditions [12].

The severity of the syndrome of motion sickness was determined after each hour of rotation, and for this purpose a special questionnaire was used; we used a point grading system for quantitative evaluations [13]. On the basis of

*The results of these studies will be reported in a separate article.



(a) (b)

Figure 1. Unit for controlling [grading] active head movements

a) diagram of photosensor [photoelectric cell?] and indicator light location in cabin
b) block diagram of unit
1-4) photosensors on side walls, ceiling and floor of cabin
5) central photosensor on front cabin wall in front of subject
6) key-operated logic unit
7) timer
8) pulse counter and decoder
9) power unit
10) movement counter
11) chronometer
12) light source
л1-л4) lamp-indicators of direction of head movement

quantitative evaluation of severity of motion sickness, we derived a mean hourly grade for each hour of rotation and it, combined with severity of motion sickness, determined endurance of rotation as a whole (see Table).

These studies were conducted on 30 essentially healthy male subjects 25-39 years of age.

Results and Discussion

A series of studies (first series) was conducted to select the graded vestibular load test provoking development of motion sickness during rotation. Five subjects participated in this study, and they presented high and average endurance of vestibular factors. Rotation was effected at the rate of 15.3 r/min. We used three variants of active head movements: 1) rapid tilts, 2) slow tilts and 3) movements in different directions (these variants are described in detail in the "Methods" section). In each variant, the subject performed 100 movements, or else stopped the test earlier in the event of onset of marked symptoms of motion sickness.

The first variant of the vestibular load test was performed in full by all subjects, and only insignificant signs of motion sickness were demonstrated:

the mean score constituted 1.8 and the severity of the nausea symptom was graded at 0.2.

Criteria of severity of motion sickness and endurance of rotation

Severity of sickness per hour of rotation		Endurance of rotation as a whole		
score	severity	severity of motion sickness during rotation	average score	endurance rating
0	0	0 and I	Up to 3	Excellent
To 4	I	I and II	4-5	Good
4-8	II	II	6-8	Satisfactory
9-12	III	II and III	9-10	Poor
Over 12	IV	III and IV	Over 10	Very poor

The second variant of the test was not completed by one of the subjects due to development of retching. The average score for the nausea symptom was 2.0 and average score for severity of motion sickness was 7.2.

The third variant of the test was performed completely by only two subjects. The others were able to perform 8 to 50 movements due to onset of severe nausea and retching.

Severity of nausea symptom averaged a score of 2.8 and motion sickness syndrome was scored at 7.8.

The results of the first series of studies enabled us to conclude that, while in a rotating cabin, active movements of the head at an arbitrary pace in different directions, i.e., movements close to man's natural ones, elicited the most distinct provocation of the motion sickness syndrome.

Moreover, the findings indicated that by using this load test one can use slower rotation, particularly in tests on subjects with average and low endurance of vestibular stimuli.

In addition to selection of load test, it was important to distribute the load in such a manner as to have a relatively stable level of severity of motion sickness for the entire period of rotation. The second series of studies was concerned with elaboration of the system of presenting graded vestibular loads during 5-h rotation.

A total of 17 subjects participated in these studies, and they had low or average resistance to vestibular factors. They were rotated at the rate of 6 r/min. We used graded head movements in different directions as a vestibular load. Three variants of load distribution were used (Figure 2A): in the first variant, we adhered to the principle of increasing the load between the 2d and 4th h of rotation; in the second version, the load was used uniformly in the 2d, 3d and 4th h; in the third variant the vestibular load test was the same in each hour of rotation. In all, the subject performed up to 50 cycles of head movements in 5 h of rotation. Each variant was tested on eight subjects.

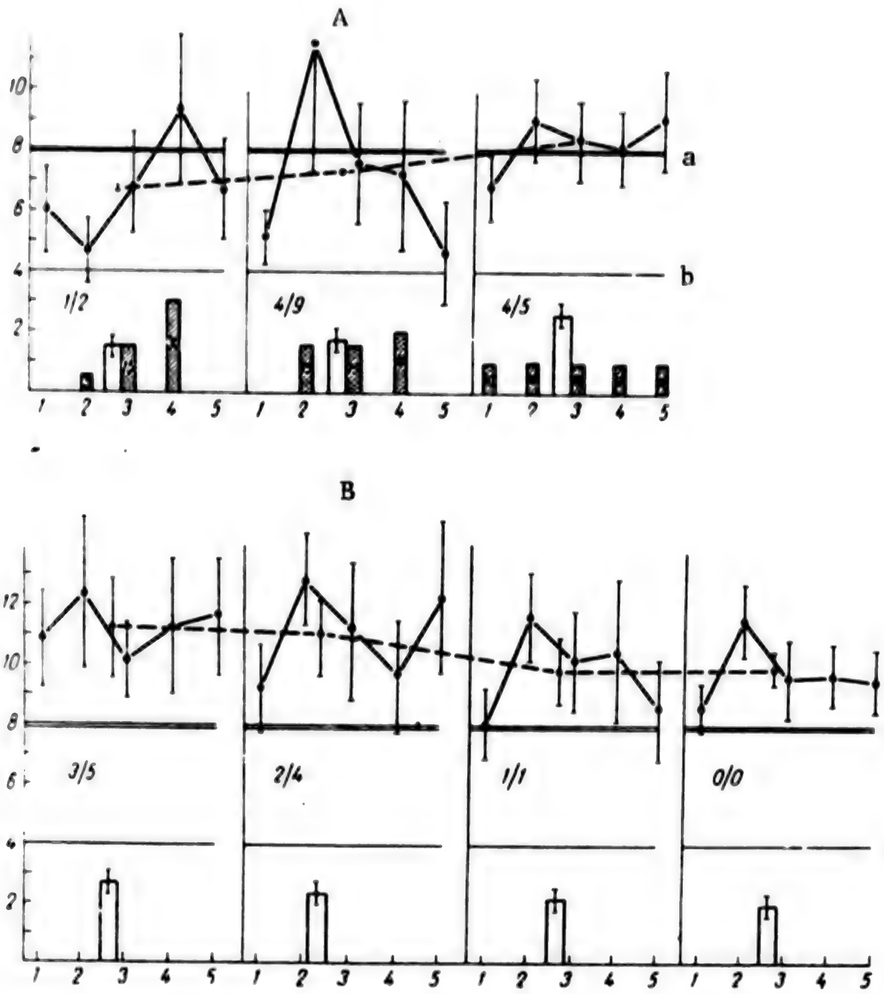


Figure 2. Severity of motion sickness simulated during prolonged rotation with different variants of distribution of graded vestibular load (A) and with repeated rotation at 2-week intervals with uniform distribution of vestibular load (B).

The solid line indicates the dynamics of severity of motion sickness (grade) during 5-h rotation; the dash line connects average levels (scores) of motion sickness. Black bars show distribution of graded vestibular loads and the numbers in them, the number of cycles of head movements; white bars indicate mean severity of nausea (score). Fractions: numerator--number of subjects who had vomiting and denominator--number of vomiting episodes. X-axis, duration of rotation (hours); y-axis, score in points.

a) top range of moderate motion sickness (grade II)
b) top range of mild motion sickness (0 and I)

There were individual variations in symptoms of motion sickness with all variants of graded vestibular load tests. However, in the first and particularly second variants, the syndrome of motion sickness was less marked in the 5th h

of rotation than in other hours. With the third variant, the symptoms did not regress, and in several subjects there was even intensification of the syndrome of motion sickness during rotation.

Vomiting episodes occured in one subject with the first variant of distribution of vestibular loads and in four subjects with the second and third variants. Nausea occurred in six subjects with the first and second variants, and in all subjects with the third. The severity of nausea averaged a score of 1.5±0.37 in the first variant, 1.6±0.42 in the second and 2.6±0.36 in the third.

The dynamics of grades for motion sickness with different variants of distribution of vestibular loads are illustrated in Figure 2A. It illustrates rather graphically that, with the third variant, there was prevalence of grade III severity of motion sickness syndrome (score of over 8). Endurance of rotation with use of the first two variants of distribution of vestibular load was rated on the average as satisfactory and with the third, as poor.

Thus, the third variant of distribution of vestibular load test turned out to be the optimum; it consisted of performing 10 cycles of graded head movements in different directions at an arbitrary pace per hour of rotation. The vestibular factors (precession accelerations) that emerged with graded head movements and arbitrary unregulated motor activity at other times reproduced in most subjects with initially low and average vestibular stability a marked syndrome of motion sickness, which persisted on the average at the same level throughout the period of rotation.

The third series of studies dealt with investigation of the effect of repeated rotation on severity of motion sickness in order to determine the duration of intervals that would be sufficient to reduce to a minimum habituation effects. It is known that, in the case of short-term rotation, week-long intervals virtually excluded development of habituation [14]. There are no analogous data with regard to long-term rotation.

Eight subjects with low initial level of vestibular stability participated in these studies. Each subject participated in four rotation periods lasting 5 h each, at the rate of 6 r/min. There were 2-week intervals between rotation periods. Motor activity, which was determined by the scheduled volume of work operations, was the same in each rotation period. The subjects performed 10 cycles per hour of head movements in different directions, and this served as graded vestibular factors.

Most subjects endured all four rotation periods equally satisfactorily. Two of them reported that they endured the last one better.

Marked symptoms of motion sickness occurred in all subjects during each period of rotation. Nausea was consistently present. Figure 2B illustrates the severity of motion sickness.

The number of subjects who developed vomiting and the number of vomiting episodes with repeated rotation sessions diminished (none of the subjects had vomiting episodes in the last rotation period). There was also a decline in severity of nausea: the score dropped from 2.7±0.39 in the first rotation period to 1.9±0.34 in the fourth. At the same time, the score for severity of

motion sickness syndrome persisted during four rotation periods at above 8 (grades III and IV severity of motion sickness).

The dynamics of severity of motion sickness syndrome demonstrated individual variations during 5-h rotation. In some subjects, there was attenuation of symptoms in different hours. However, on the whole, endurance of rotation, as assessed by severity of motion sickness over the 5-h period, did not improve in any subjects when submitted to repeated rotation; three subjects endured the last rotation worse than the first. On the average, endurance of the first two rotation periods was rated as very poor and the last two as poor.

On the basis of the results obtained in the third series, it can be concluded that, with repeated 5-h rotation sessions at 2-week intervals, elements of habituation were demonstrable only with regard to nausea and vomiting symptoms. On the whole, the severity of the syndrome of motion sickness remained high throughout the tests.

Thus, we have developed a model of motion sickness, which included 5-h rotation during which the subjects are able to perform active movements and displacements. Standardization of vestibular stimuli is obtained by performing active head movements in different directions, which are graded in amplitude and number, during each hour of rotation. In subjects with a predisposition for motion sickness, marked signs of this sickness developed during rotation at 6 r/min. The rate of rotation can be increased for subjects with greater resistance to vestibular stimuli. With repeated rotation sessions at 2-week intervals, there was virtually no change in severity of the motion sickness syndrome, and this is important to use of this model to assess the efficacy of agents against motion sickness.

The similarity of the developed model to the space form of motion sickness warrants the belief that its use may be effective in studies dealing with a search for reliable agents for prevention of vestibular dysfunctions during spaceflights.

The model, which was developed for use in studies of efficacy of pharmacological agents against motion sickness, may find application in studies of other aspects of the problem of motion sickness.

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EVALUATION OF EFFECT OF 70 dB NOISE ON MAN

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 28 May 82) pp 78-81

[Article by G. I. Tarasenko and I. A. Petlenko]

[Text] Scientific investigation of the adverse effects of noise on animals and man was originated by the basic research of Vittmak [1], who demonstrated the link between an acoustic factor and irreversible changes in hair cells of the spiral [Corti's] organ. For a long time, otorhinolaryngologists dealt with occupational pathology related to noise, since it was believed that deafness is, if not the only manifestation, the main one of the deleterious effects of excessive noise. The next stage, which altered the approach to interpretation of pathophysiological mechanisms of adverse acoustic effects on man was the teaching on noise sickness, which was substantiated by Soviet hygienists and occupational pathologists [2, 3]. It was shown that, in addition to the auditory analyzer, noise affects the central nervous and cardiovascular systems, as well as other body functions. Occasionally, such nonauditory effects are manifested earlier and trouble workers more than hearing impairment. It was demonstrated that workers exposed to noise sometimes present decreased work capacity and higher general morbidity rate [4]. For this reason, it is important to further refine the methods and criteria for assessing the overall adverse effect of noise.

It should be noted that the greatest difficulties arise when one tries to establish the early manifestations of the adverse effects of long-term noise of moderate intensity [5-9]. As we know, continuous generation of noise of moderate intensity is inherent in the orbital phase of spaceflights [5].

During actual work, noise of moderate intensity elicits temporary changes in auditory thresholds, which are often insignificant and do not exceed the range of daily and temporary fluctuation. These limited fluctuations can also be attributed to the nonspecific (reflex) effect of other environmental factors on the auditory system. At the same time, reactions referable to the central nervous and cardiovascular systems, as well as other functional changes in the body, could be elicited both by acoustic stimuli and other environmental factors.

We undertook this study in order to validate the optimum set of methods that would permit more accurate determination of the dynamics of the subjects' state and admissibility of noise of moderate intensity.

Methods

In our research, the subjects were exposed continuously to a noise of 70 dB A for 1, 4, 24 h and 12-24 days. Other functions, physical and chemical environmental factors were in the range of physiological and hygienic standards. In all series of studies, we evaluated hearing by means of tonal and verbal audiometry, determination of level of discomfort with regard to volume and reaction of auditory thresholds in the 10th min of exposure to 105 dB noise. We used the findings of a physiological work-up (electrocardiography, rheoencephalography, respiratory rate, blood pressure) to assess nonspecific systemic reactions. We also used psychophysiological methods: finding numbers on black and red tables, counting aloud, time reflex, reaction to moving object. These methods are used extensively to assess the physiological status of subjects and psychophysiological reactions to exogenous stimuli.

We must discuss the methods of grading subjective noise tolerance. In the 20-day studies we used two noise rating scales: volume and disturbing effect (unpleasantness). Various gradations of volume and unpleasantness of noise were assigned the following rank indexes: 1--weak, indifferent; 2--noticeable, disturbing; 3--perceptible, disturbing; 4--rather significant, irritating; 5--strong, unpleasant; 6--very strong, extremely unpleasant; 7--unendurable, eliciting pain.

We used the SAN* test as an integral method of assessing the state of the body and work capacity, which enabled us to keep dynamic subjective grading according to psychophysiological parameters such as well-being, activity and mood [10].

In studying the effect of noise of moderate intensity, it was of special interest to determine the role and significance of modality of noise in changes in hearing function. For this purpose, we used 2 types of stimuli as a 10-min load test: "white" noise and musical excerpts equivalent in energy to noise. A comparison of reactions of auditory sensitivity to these different loads enabled us to asses with greater validation the efficacy of functional music, which is gaining increasing use recently in a number of industries where noise is present.

Results and Discussion

The results of the studies confirmed previous conclusions [2, 3, 5] to the effect that noise of moderate intensity (70 dB A) can be assessed, with regard to its influence on the body, only with consideration of a set of parameters reflecting the reaction of the auditory system, general physiological functions and subjective complaints. Already with 1-h exposure, there was some change in hearing reaction to the next functional load. With increase in exposure time, there was increase in number of psychophysiological and subjective manifestations characterizing the degree of adverse "nonauditory" effects. There was prevalence of the role of subjective reactions, since physiological changes were unreliable.

Among the methods used, the SAN test was the most informative, as it indicated onset of fatigue of the central nervous system, which was manifested by worsening

*Translator's note: SAN are the initial letters for Russian words for well-being, activity and mood [affect], respectively.

of well-being, diminished motivation for work, activity and interest in the work being performed, asthenization, etc. The Table lists the results of the SAN test in the course of the 20-day study.

Dynamics of data obtained with SAN test

Parameter	Day of study									
	1		5		10		15		20	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Subject K.										
Well-being	64	69	58	65	57	57	47	51	47	49
Activity	55	62	50	58	45	58	43	46	44	48
Mood	68	67	60	62	58	59	47	46	47	47
Subject R.										
Well-being	53	67	47	67	43	60	41	58	43	57
Activity	48	64	41	61	39	52	38	48	47	48
Mood	58	61	52	57	46	53	44	55	46	53

The results of scaling subjective psychoacoustic reactions conformed well with the data obtained in the SAN test. These studies demonstrated the dynamics of change in subjective assessment of noise and individual reactions (Figure 1). For example, subject R. rated noise volume as "perceptible" (index 3) and "noticeable" (index 2) from the 1st to 7th days, and as "weak" (index 1) after the 7th day, and from that time on instead of "disturbing" (index 3) and only at times "indifferent" the noise became constantly "indifferent."

The mean index for subject R. was 2 for volume, and the same score was obtained for the disturbing effect of noise. Evidently, elevation of hearing thresholds in this subject reflected adaptation to the noise sitmulus, which persisted to the end of the test period. This was not associated with decline of performance indicators, although signs of fatigue did appear.

Subject K. assessed noise volume as "perceptible" (index 3) on the 1st day, then as "weak" (index 1) up to the 15th day and "perceptible" for the next 5 days; in these periods, the noise was "indifferent" (index 1), then "irritating" (index 4). The mean indexes for this subject were 2.3 and 2.5. This indicates that, after a certain period of "working into" the noise conditions, which was associated with transient adaptation, there was depletion of his compensatory mechanisms and diminished endurance of the noise factor.

Thus, the dynamics of changes in parameters of subjective state and the subjects' assessment of the disturbing and irritating effects of noise were particularly informative with respect to individual tolerance of noise, and this is of considerable interest to both screening operators for work in a noisy environment and forecasting their ongoing state and significance of presented complaints.

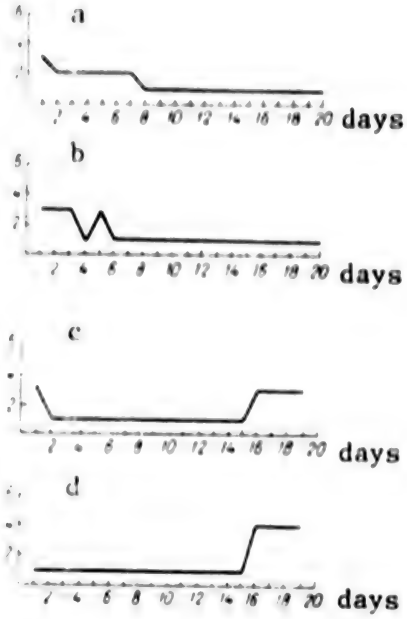

Figure 1.
Dynamics of subjective rating of volume (a, c) and nature (b, d) of noise of moderate intensity by subjects R. and K. in the course of 20-day study

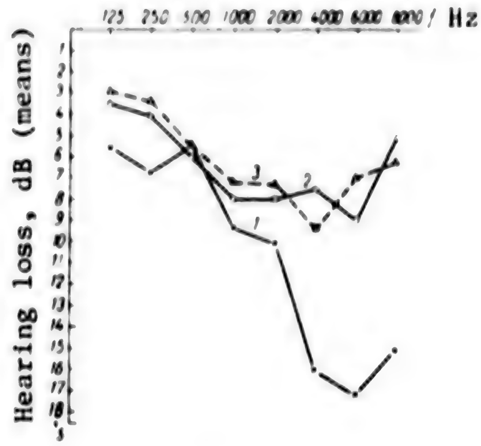

Figure 2.
Averaged audiograms obtained after 10-min functional tests differing in modality. Energy parameters of the loads are equivalent
1) 105 dB noise
2) music
3) 105 dB noise with interjections of music

Studies involving use of 10-min audio loads of different modality (of equivalent energy) against the general background of noise (Figure 2) were pursued in order to elaborate some principles for protecting hearing against noise. The hearing thresholds underwent significant changes only with exposure to 105 dB A noise. The results of the test involving use of music of the same intensity, however, confirmed the desirability of using musical inserts in noisy work environments to reduce (attenuate) the fatiguing effect of noise on the central nervous system and auditory analyzer of workers.

The obtained data confirm the thesis expounded by L. A. Orbeli [7] to the effect that the reaction of the auditory system to an audio stimulus should be viewed as a complex process, which depends not only on the force of the sound but excitability of the central nervous system, which alters the lability and excitability of the auditory analyzer. This thesis was also confirmed in the part of our studies dealing with informativeness of noise as an exposure factor. Figure 2 shows how the mean hearing thresholds of the subjects changed during 10-min exposure to "white" noise of 105 dB A, purely musical excerpt of the same intensity and combination of noise and music, again with overall intensity of 105 dB A. According to these data, the hearing thresholds undergo considerable changes only with exposure to the noise factor. Musical loads, which were selected with consideration of the subjects' taste, elicited a considerably smaller fatiguing effect. This shows that use of various audio factors ["applications"] in the presence of noise of moderate intensity is physiologically warranted and can serve as one of the means of protecting people against the adverse effects of noise.

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MODIFIED REBREATHING METHOD FOR DETERMINATION OF CARDIAC OUTPUT WITH INCREASING EXERCISE LOADS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 23 Apr 82) pp 81-83

[Article by V. I. Gavrilenkov, V. V. Gritsenko and O. Yu. Mochalov]

[Text] The rebreathing (RB) method, which is used to determine cardiac output (CV) [minute volume of circulation] during physical exercise, has been recognized as the method of choice in recent years, in view of its safety, possibility of numerous and rapid repetition, relatively simplicity of performance and high reproducibility of results [2-4, 5, 6, 7, 11, 13, 14]. When CV (in ℓ/min) is determined by the RB method, it is calculated using the Fick formula:

$$Q = \frac{\dot{V}CO_2}{p_vCO_2 - p_aCO_2}$$

where $\dot{V}CO_2$ is CO_2 output (mℓ/min STPD), p_vCO_2 is CO_2 tension in mixed venous blood (mℓ/ℓ), p_aCO_2 is CO_2 tension in arterial blood (mℓ/ℓ). This method permits calculation of p_vCO_2 and p_aCO_2 without resorting to catheterization of the heart.

However, there are some appreciable methodological difficulties in determining CO_2 tension of mixed venous (p_vCO_2) and arterial (p_aCO_2) blood during exercise. When determining p_vCO_2 by the well-known method of Collier [10] during intensive exercise, these difficulties are attributable to the fact that during rebreathing in the lungs-bag system, because blood recirculation time is reduced to 6-8 s, p_vCO_2 does not have time to become equalized with partial CO_2 tension of respiratory air (pCO_2). The absence, in such a case, of the "plateau" phenomenon on the capnogram, which reflects the true value of p_vCO_2, makes it virtually impossible to determine CO_2 tension in mixed venous blood during exercise. For this reason, the Collier method did not gain wide use in the study of CV during exercise. Indirect methods are used to find p_vCO_2, which are based on extrapolation or mathematical processing by the formula of data on dynamics of change in pCO_2 in respiratory air during rebreathing [11, 15]. However, the latter permit determination of values that are only close to the true p_vCO_2.

When studying CV by the RB method, p_aCO_2 is evaluated according to partial CO_2 tension in the alveolar portion of exhaled gas (p_ACO_2). However, there are

still difficulties in the method of collecting a true portion of alveolar gas in determining p_aCO_2 from the p_ACO_2 and, accordingly, in finding on the capnogram the CO_2 content that reliably reflects p_aCO_2. This difficulty is due to the fact that determination of p_aCO_2 from p_ACO_2 has a flaw because of the presence of the so-called arterial-alveolar (a-A) CO_2 gradient. Formation of the (a-A) CO_2 gradient is related to the fact that, in the initial alveolar portion of exhaled air, pCO_2 is lower than in arterial blood. In the last portion of exhaled alveolar air, pCO_2 rises constantly and starts to exceed pCO_2 in arterial blood--there is formation of a negative (a-A) CO_2 gradient. At the end of expiration, CO_2 coming from mixed venous blood is distributed over an ever decreasing volume of alveolar gas, and its concentration in this gas progressively increases. During exercise, when expiration time is shorter and its depth drastically increased, (a-A) CO_2 gradient becomes significant [6, 7]. In a number of individuals, when alveolar gas is collected by the usual method (from the valve box) and breathing is shallow, the maximum demonstrable CO_2 level on the capnogram that reflects p_ACO_2 is lower than the true value of p_aCO_2, i.e., a positive (a-A) CO_2 gradient is formed. As a rule the value of this gradient is low, constituting ±2.5 mm Hg. However, there can be significant error in calculating CV by the RB method, particularly if it is used during exercise [6, 12]. For this reason, in calculating p_aCO_2 some authors [11, 13] take into consideration the (a-A) CO_2 gradient, computing it with consideration of tidal volume and dead space, while others [6, 15] calculate the (a-A) CO_2 gradient with consideration of the intensity of exercise. These methods of determining the (a-A) CO_2 gradient did not gain wide use because of the fact that the calculations are approximate and time-consuming [2-4, 8, 14].

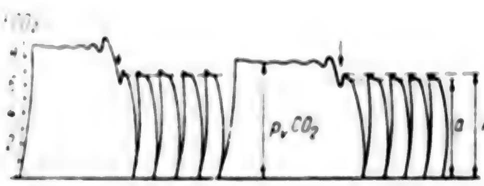

Figure 1.
Capnogram at rest (right) and with 25-W exercise load. Arrowheads show start of RB.
FCO_2) scale of CO_2 concentration in exhaled air (%)

In order to obtain the true values of p_vCO_2 by the Collier method during exercise of increasing intensity from 25 W to its limit, one should use a gas mixture with somewhat higher CO_2 content than the predicted p_vCO_2 for a specific exercise load, as well as a volume of gas mixture that would be sufficient for free use of RB. Proper individual selection of volume and composition of the gas mixture assures optimum conditions for rapid equilibration of pCO_2 and p_vCO_2 during RB in the course of intensive exercise within a short blood recirculation time (6-8 s).

Since the RB system is connected after complete expiration and the respiratory volume at maximum exercise loads constitutes 2/3 of vital lung capacity, it was suggested to use a volume of gas mixture in the breathing bag equalized to the subjects' vital capacity. In order to determine the composition of gas mixture, in which pCO_2 somewhat exceeds p_vCO_2 with a specifically increasing load, we recommend the following method of selecting CO_2 of the gas mixture in the breathing bag, which was developed in a preliminary study.

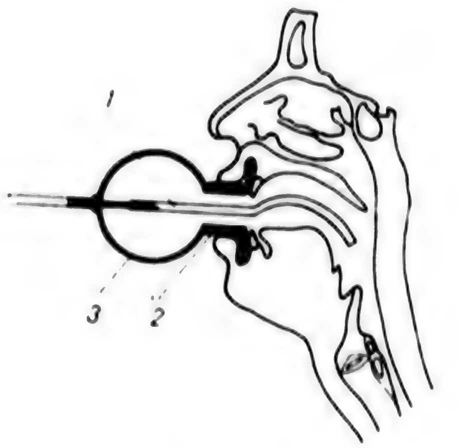

Figure 2.
Device for collecting exhaled air from stomatopharyngeal cavity
1) catheter
2) mouthpiece
3) valve box

When performing RB at rest, we used a gas mixture containing 7.5-8% CO_2, in which partial CO_2 pressure exceeded somewhat p_vCO_2 at rest [8]. Prior to RB during exercise of 25 W, the CO_2 content of the gas mixture in the breathing bag (we refer to the "plateau" CO_2 level after RB at rest) increased by 1.5%. In order to then obtain a pCO_2 in the gas mixture that would exceed somewhat the p_vCO_2 of the next load (50-75-100-125-150-175-200 W, etc.), the CO_2 content in the breathing bag, which had become established after RB at the preceding exercise level, increased by 1% (Figure 1). Adherence to this method of selecting the gas mixture enabled us to obtain on the capnogram a "plateau" in all instances, with RB associated with increasing exercise loads and, consequently, we also obtained the true tension of CO_2 in mixed venous blood.

The required gas mixture was obtained in the breathing bag by means of precision reducers [reducing valves] MSZ-4316 (Hungarian People's Republic) under capnographic monitoring, from two tanks containing O_2 and CO_2. $\dot{V}CO_2$ was determined by the open method of Douglas-Haldane.

In order to improve collection of the last alveolar batch of gas and obtain by the direct method the true "alveolar plateau" on the capnogram, which corresponded to p_aCO_2, we took samples of exhaled gas from the stomatopharynx, rather than the valve box, using a specially curved catheter (Figure 2). The length of the catheter was 10-12 cm and its inside diameter was 0,5 cm. When breathing through the mouthpiece, the buccal cavity and stomatopharynx were enlarged in volume, the palatine uvula was deflected toward the posterior wall of the pharynx and the catheter remained freely in the stomatopharynx without eliciting the vomiting reflex or other unpleasant sensations.

This device made it possible to record on the capnogram at the end of each expiration the time of equilibration of p_aCO_2 and p_ACO_2 (true "alveolar plateau") and (a-A) CO_2 gradient (see Figure 1). A comparison of p_aCO_2 data obtained by the modified capnographic method and the Astrup micromethod in the modification of Ziggard-Anderson revealed that the results were very comparable--±1 mm Hg [1].

Statistical processing of the results of repeated determination of CV in health conditioned and unconditioned individuals with use of increasing physical loads over the entire range of the tests revealed that they were highly reproducible and reliable (coefficient of variation did not exceed 3.4%, maximum standard deviation constituted 0.3 ℓ/min).

The proposed modified RB method for determination of cardiac output during increasing exercise loads expands the possibilities for studying the functional

reserve of the cardiovascular system under laboratory conditions and in clinical practice.

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BRIEF REPORTS

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EFFECTS OF DIHYDROERGOTAMINE AND SYDNOCARB ON MAN'S ORTHOSTATIC STABILITY WITH ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 29 Sep 82) pp 83-84

[Article by O. D. Anashkin and A. Yu. Modin]

[Text] Correction of the set of functional changes that develop after flights and are manifested, in particular, by worsening of orthostatic stability, is among the urgent problems of space medicine. In the opinion of a wide circle of researchers [1-5], deconditioning of the cardiovascular system is an important factor in orthostatic intolerance arising under the effect of weightlessness.

There are several works in the Soviet and foreign literature with information about the effects of pharmacological agents referable to different groups on orthostatic stability [6-8], or with discussion of their potential use when such stability was diminished [9-10].

We tested the effects of the venopressor ["vein toning"] agent, dihydroergotamine (DHE), and sympathomiment stimulator of the central nervous system, sydnocarb, on orthostatic stability of man experiencing hypokinesia.

Methods

These studies were conducted on 9 essentially healthy men 30-39 years of age (height 171-185 cm, weight 58-88 kg). The subjects were at a hospital on the usual food allowance (3500 kcal/day). Fluid intake was not limited. The physiological effects of weightlessness were simulated with 6-h antiorthostatic [head-down] hypokinesia (AOH) with a -15°tilt [11].

We used the standard 20-min orthostatic test with +75° tilt to study orthostatic stability.

During the test, we recorded the EKG continuously in the DS lead, and we made discrete determination of blood pressure using the Medicor (Hungarian People's Republic) automatic gauge.

We conducted four series of studies, in which clinical and physiological examinations were made following the same program. All of the subjects

participated in all of the test series (the intervals between series lasted at least 14 days).

In the first series, the subjects were on an ordinary exercise [movement] regimen; in the second they were given placebo 30 min before and in the 3d and 5th hours of AOH; in the third series, the subjects were given sydnocarb 30 min before AOH (5 mg) and in the 3d and 5th hours of hypokinesia (10 mg at a time).

In the fourth series, the subjects took dihydroergotamine (Spofa, CSSR), on the same program as placebo and sydnocarb, to a total dosage of 6 mg.

The agents were taken by mouth.

The results of these studies were processed by the method of variants linked in pairs, using Student's *t* criterion to assess the reliability of mean differences.

Results and Discussion

In the first series, 1 out of 8 subjects observed collapse in the 20th min of the orthostatic test. It should be noted that a collaptoid reaction was also demonstrated in this subject in subsequent series. After AOH with intake of placebo, 2 collapses were noted during the orthotest, with intake of sydnocarb there was 1 and with intake of DHE--4.

The Table shows that the mean heart rate (HR) recorded before the test, with the subjects in horizontal position, presented no reliable differences in any of the series. During the orthostatic test after 6-h AOH, with intake of placebo there was reliable 7.4% increase in maximum HR; maximum increment thereof was 30%.

Effects of pharmacological agents on human orthostatic stability

Parameter	Series			
	I	II	III	IV
Number of collapses	1	2	1	4
HR before test, per min	65	63	63	61
Maximum HR during test, per min	95	102*	98*	98
Maximum HR increment, per min	30	39*	35	37
Systolic pressure, mm Hg:				
before test	129	130	125	130
during test	128	123	131**	133**
Diastolic pressure, mm Hg:				
before test	76	81	80	80
during test	89	84	94**	91**
Pulse pressure, mm Hg:				
before test	53	49	45	50
during test	39	39	37	42

Note: Mean results of 8 cases are listed. One asterisk indicates P<0.05, as compared to corresponding result in first series using the method of pair-related variants; two asterisks indicate P<0.05, as compared to the corresponding result in the second series, using the same method.

A comparison of systolic, diastolic and pulse pressure readings for the first and second series of studies failed to demonstrate reliable differences; however, there was a tendency toward decline of systolic and diastolic pressure in response to the orthostatic factor under the effect of AOH. Pulse pressure showed virtually no change.

When sydnocarb was given, we observed during the test a reliable decline of maximum HR, reliable elevation of systolic and diastolic pressure, a tendency toward decline of maximum HR increment, as compared to parameters with intake of placebo.

With intake of DHE, maximum HR and its maximum increment during the orthostatic test presented some tendency toward decline, and the effect of DHE on blood pressure was manifested by a reliable elevation of systolic pressure by a mean of 10 mm Hg and diastolic, by 7 mm Hg.

The average drop of pulse pressure during the orthostatic test constituted 14 mm Hg in the first series, 10 mm Hg in the second and 8 mm Hg in the third and fourth series.

Thus, it was demonstrated that 6-h AOH worsens orthostatic stability of man.

With intake of sydnocarb, after 6-h hypokinesia orthostatic stability was better than after intake of placebo. We previously demonstrated that sydnocarb has a beneficial effect on functional state of the cardiorespiratory system in the case of 7-day water immersion [12]. Evidently, the positive effect of sydnocarb on orthostatic stability after AOH is related to its sympathomimetic properties [13, 14].

With intake of DHE, we could have expected improvement of orthostatic stability since, according to the data of a number of authors [9], DHE reduces deposition of blood in veins of the lower extremities during postural tests and increases venous influx to the heart. It is known that DHE is a central inhibitor of sympathetic tonus and this can, perhaps, explain the worsening of orthostatic stability when this agent is prescribed.

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MORPHOLOGICAL COMPOSITION OF HUMAN BLOOD AND CYTOCHEMICAL REACTIONS OF LEUKOCYTES AS RELATED TO LONG-TERM EXPOSURE TO LOW CONCENTRATIONS OF AMMONIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 9 Mar 82) pp 85-86

[Article by M. P. Kalandarova]

[Text] By virtue of its reactivity, blood plays an important part in constitutional resistance and development of adaptation when there is exposure to diverse deleterious exogenous factors. Evaluation of functional state of the cell by means of cytochemical methods of testing activity of different enzymes is very important to the study of the effects of toxic agents in concentrations that do not yet create clearcut clinical signs of disease, which occurs with minor changes in hematological parameters or without quantitative changes in morphological composition of blood.

Methods

These studies were conducted on 8 subjects who stayed in a pressure chamber with ammonia concentration in air of 2.0±0.1 and 5.2±0.1 mg/m^3 for 12 days. Ambient temperature constituted 26-27°C and relative humidity 60-70% for 9 days, and on the other days the values were 20-22°C and 40-50%, respectively, with 20-21% oxygen and 0.1-0.4% carbon dioxide content. We determined the erythrocyte count, hemoglobin, reticulocytes, thrombocytes, leukocytes and their different forms (on the hemogram). Cytochemical reactions in leukocytes were assessed by the Kaplow method as modified by Astaldi and Verga [1], which is based on quantitative assay of stained substance in the cell. We determined the quantity of positively reacting cells (percentage), as well as mean cytochemical coefficient.

Results and Discussion

Erythrocyte count, hemoglobin and reticulocyte content of blood conformed to normal values under the effect of ammonia in a concentration of 2.0±0.1 mg/m^3 combined with an unfavorable microclimate (temperature 26-27°C, relative humidity 60-70%). The thrombocyte count was also in the normal range. Leukocyte, neutrophil, lymphocyte, eosinophil and basophil levels did not differ appreciably from base values. Starting on the 9th day, we demonstrated some increase in stab neutrophils (to 400±55/mm^3 versus 210±82/mm^3 blood as the

base value). There was an increase in monocyte content (to 680±130/mm^3 blood, versus the normal 360-430) throughout the observation period. Previously [9], in a study where ammonia content in the chamber constituted 2 mg/m^3 and with optimum microclimate parameters (temperature 20°C, relative humidity 30-40%), it was demonstrated that the morphological composition of subjects' blood did not differ from background values. Peroxidase activity was diminished on the 9th and 20th days of the study. In particular, there was a decline on the 9th day of mean cytochemical coefficient (1.75, versus the norm of 2.8) due to decrease in share of cells with grade III reaction in the overall balance of positively reacting cells (30.5±7.6%, versus 84.0±2.5% as the base level) and a rather large number of cells with zero activity (13.0±3.9%, with none present prior to the tests). We failed to demonstrate noticeable differences in glycogen content of leukocytes in the course of the study, as compared to the background level. Lipid content of leukocytes conformed to normal throughout the study period.

With exposure to ammonia in a concentration of 5.2±0.1 mg/m^3 combined with unfavorable microclimate, erythrocyte and hemoglobin were in the range of base values. We failed to demonstrate deviations from normal in reticulocyte, thrombocyte and leukocyte counts. There was no clearcut pattern of change in hemogram parameters either. We should mention that there was some neutropenia (1900±400 neutrophils/mm^3 blood), a stab neutrophil shift, moderate monocytosis (to 710±230/mm^3 blood), lymphocytosis (3200±420/mm^3 blood) at some stages of the study. Peroxidase activity conformed to normal values throughout virtually the entire test period. The 20th day was an exception, when peroxidase activity was somewhat diminished. There was a decrease in number of leukocytes with grade III reaction (to 73.3±10.4%, versus 88±6.4% normal) and increase in those with grade I reaction (to 14.2±5.8%, versus 2.0±1.1%), as a result of which the mean cytochemical coefficient was diminished (2.4 versus 2.85). Glycogen content of leukocytes did not change over the entire observation period. The percentage of positively reacting cells and mean cytochemical coefficient were in the normal range (97.3±1.6%-100±0% and 2.7-2.9, respectively). An analogous pattern was demonstrated in lipid content.

Thus, under the effect of ammonia concentration of 2.0±0.1 mg/m^3 in the atmosphere combined with unfavorable microclimate in the pressure chamber (26-30°C and humidity of 70-80%), we observed a stab shift and monocytosis, whereas with ammonia present in a concentration of 5.2±0.1 mg/m^3, under the same microclimate conditions, there was neutropenia, a stab shift, monocytosis and (periodically) lymphocytosis.

The stab shift in the absence of noticeable leukocyte and neutrophil reaction is indicative of intensity of neutrophilopoiesis (exit of stab neutrophils from the bone marrow reservoir). The monocyte reaction, which we demonstrated in the subjects, reflects body reactivity. Blood monocytes and tissue macrophages are presently viewed as the most important cellular mechanisms of nonspecific resistance. As they perform their protective function, monocytes prevent dissemination of pathogenic microorganisms, absorb and destroy endotoxins, and they participate in immunogenesis. The possibility cannot be ruled out that monocytosis is, to some extent, a reflection of the body's reaction to accumulation of nonmetabolized metabolic products under the influence of the above-mentioned adverse environmental factors [2-5]. The decrease in peroxidase activity should be interpreted as an unfavorable sign

indicative of diminished protective function of neutrophils, in particular, of bactericidal activity [6, 7]. It is known that there is a decrease in constitutional resistance to various infections during spaceflgiths [8].

The blood system plays an important role in producing defense factors in the mechanisms of immunity; for this reason, our findings could be taken into consideration in validating the maximum permissible concentrations for the case of long-term continuous content with low levels of ammonia in the atmosphere of pressurized compartments, combined with other deleterious ambient factors, such as high temperature and humidity.

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LETTERS TO THE EDITOR

UDC: 629.78:612.014.477-064:616.281

BILATERAL GALVANIZATION OF LABYRINTHS USED TO SIMULATE CHANGES IN VESTIBULAR AFFERENTATION IN WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (manuscript received 6 Jul 82) pp 86-88

[Article by Ye. B. Shul'zhenko, G. I. Gorgiladze and V. G. Kozlova]

[Text] It is generally recognized at the present time that spaceflight conditions lead to changes in vestibular function. There are no postural or righting reflexes in weightlessness, and there is depression of afferentation from otolith receptors for a long period of time [1-3]. Can one simulate on earth the state of weightlessness for the vestibular system?

We believe that one can simulate changes in vestibular afferentation inherent in weightlessness with use of galvanic current to the vestibular system.

It has been established that passing direct current of a specific direction through the labyrinths is associated with consistent changes in impulsation afferent activity of the vestibular nerve and neurons of vestibular nuclei [4-8]. In particular, application of the anode to one labyrinth elicits vestibular afferentation and background impulsation of the vast majority of neurons of vestibular nuclei on the stimulated side. At the same time, activity of most neurons of vestibular nuclei on the contralateral side is enhanced. As a result of impairment of equilibrium of vestibular centers, there is appearance of deviation of the eyes and nystagmus, autonomic, asymmetrical postural reactions, changes in overall and impulsation activity of neurons in various subcortical structures and cerebral cortex [6-13]. This is associated with development of distinct activation on the electrocorticogram (ECoG) in the form of depression of slow, high-amplitude bioelectric potentials and appearance of high-frequency, low-amplitude waves (Figure 1).

Application of the anode to both labyrinths (so-called binaural, monopolar, or equal galvanization) leads to depression of background impulsation of nuclear neurons on both sides, whereas activation is usually absent on the ECoG). Moreover, there is considerable intensification and slow and high-amplitude waves (see Figure 1). It is opportune to recall here that similar ECoG findings were made on animals submitted to bilateral labyrinthectomy, transection of both 8th nerves or destruction of vestibular nuclei, as well as during short-term weightlessness [10, 14-16]. When direct current of a descending direction is passed through both labyrinths, there is depression and even complete elimination

of vestibular function. There is also distinct depression of the counter-rotation reaction of the eyes in response to lateral rocking, disappearance of labyrinthine righting reflex for the head, jumping reflex, reaction of turning over in the air during free fall and the elevator reaction (Figure 2).

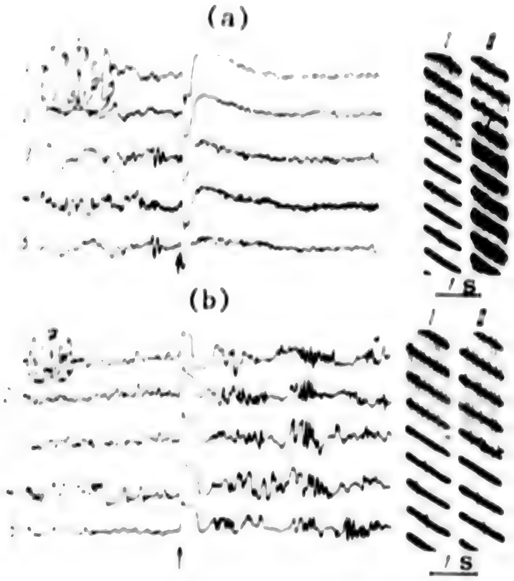

Figure 1.
Effect of galvanization of labyrinths on ECoG and discharges of two neurons from the right (I) and left (II) Deiters' nuclei. Nonanesthetized cats given curare. Cerebellum is resected [15].

a) reaction to application of anode to right labyrinth (cathode on silent electrode applied to occipital muscles)
b) reaction to application of anode to both labyrinths; arrowheads show time of delivery of 0.45 mA current

What is the mechanism of depression of vestibular afferentation in response to delivery of descending direct current to the labyrinth? According to data in the literature, this phenomenon occurs as a result of hyperpolarization of membrane potential of sensory labyrinthine cells, endings of vestibular afferent fibers and neurons of vestibular ganglion [4, 5, 8]. True, with the usual methods of galvanization, direct current does not have selective action, since it alters afferentation from both the otoliths and semicircular canals [17].

Figure 3 illustrates the bilateral connections between vestibular nuclei on both sides. This diagram shows how impulsation of neurons of vestibular nuclei is depressed [9, 10] when direct current of a descending direction is passed through both labyrinths.

Studies of healthy subjects revealed that binaural monopolar galvanization with descending current of 5-7 mA for 10-30 s leads to shifting of the body's center of gravity to the back (Figure 4). With analogous treatment under conditions of "dry" immersion [18] and in the dark, typical illusions occur: sensation of abrupt elevation, drop, soaring, lightness and complete disorientation. The sensation of a "sinking" heart and breath-holding. It is known that such reactions occur during parabolic flights [19, 20].

In our opinion, the existing methods of simulating the physiological effects of weightlessness on earth [21] will become more universal if they include equal galvanization of the labyrinths.

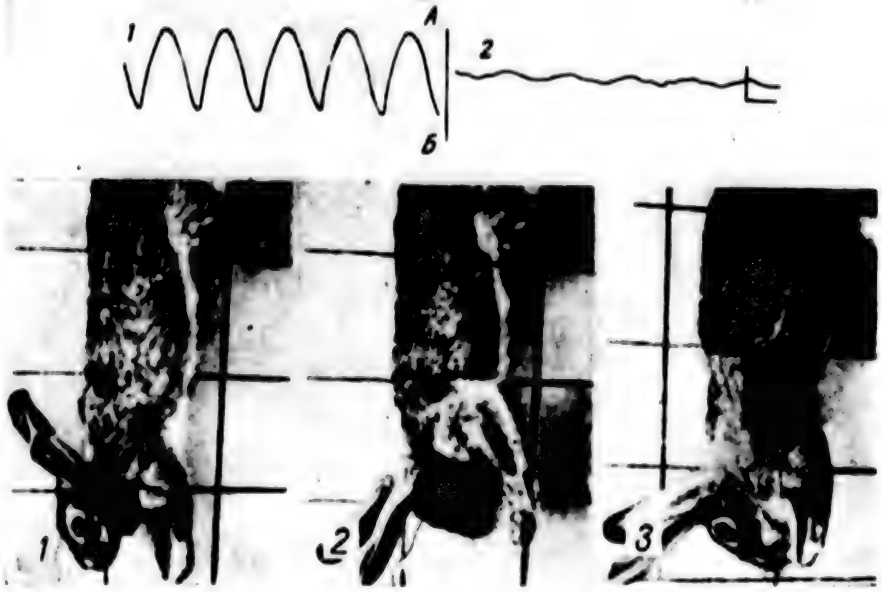

Figure 2. Effect of galvanization of labyrinths with descending direct current on reaction of counter-rotation of the eyes and head position in space in the rabbit

А) tracing of eye movements when animal is rocking about the long axis of the body (inclinations to the right at 45° at a frequency of 0.25 Hz)
1 and 2) before and during passage of 30 mA current through labyrinths; calibration 15°, 2 s

Б) appearance of animal in intact state with head down (1), during passage of 3.0 mA current through labyrinths (2) and after bilateral labyrinthectomy (3)

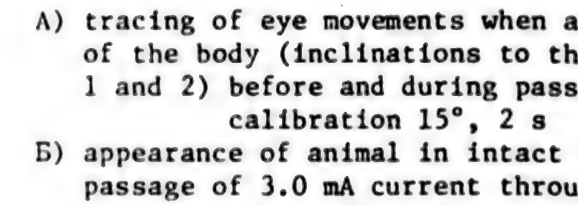

Figure 3.
Drawing of bilateral commissural connections between vestibular nuclei on both sides. For more graphic illustration, connections are shown in only one direction

a',a") commissural neurons
b',b",b"') inhibitory neurons
1) inhibitory (reciprocal) link
2) excitatory (synergistic) link

Large circles show nuclear neurons with ascending and descending efferent links (modification of diagram in [9]).

Figure 4.
Effect of labyrinth galvanization with direct current in descending direction on fluctuation of general center of gravity of the body of a healthy subject in the dark. Anode on both labyrinths, cathode on silent electrode on dorsal surface of neck. F and C--frontal and sagittal stabilograms, respectively. Deviation of sagittal stabilogram to the right corresponds to backward shift of center of gravity. Top curve is mark of stimulation with 6.0 mA current. Time scale 10 s.

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CURRENT EVENTS AND INFORMATION

UDC: 613.693:061.3(47+57)"1982"

SEVENTH ALL-UNION CONFERENCE ON SPACE BIOLOGY AND AEROSPACE MEDICINE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 17, No 3, May-Jun 83 (signed to press 6 Apr 83) pp 88-94

[Article by editorial board]

[Text] The 7th All-Union Conference on Space Biology and Aerospace Medicine, which was organized by the USSR Ministry of Health, Institute of Biomedical Problems of the USSR Ministry of Health, All-Union Society of Physiologists imeni I. P. Pavlov and State Museum of History of Cosmonautics imeni K. E. Tsiolkovskiy, convened in Kaluga on 30 June to 2 July 1982.

More than 25 specialists from different cities of our country, as well as scientists from a number of other countries (Polish People's Republic, CSSR, People's Republic of Bulgaria, Hungarian People's Republic, GDR, India, Cuba, United States, France, FRG) participated in the work of the conference; most of the foreign scientists are collaborating fruitfully with Soviet scientists on programs of the "Intercosmos" Council. Administrators of Party and soviet organizations in Kaluga and Kaluga Oblast, as well as representatives from the State Museum of History of Cosmonautics imeni K. E. Tsiolkovskiy, devoted much attention to the work of the conference. The Kaluga Standards Printing House was very helpful in publishing the proceedings of the conference.

The conference convened under the slogan of "Achievements of space biology and aerospace medicine in the service of practice."

Academician O. G. GAZENKO delivered the opening remarks and headed the work of the conference. He expressed his satisfaction with the broad representation at the conference of Soviet and foreign scientists, and he defined the main directions of work of the conference. O. G. Gazenko noted that the contents of the delivered papers are indicative of formation of a new stage in the development of cosmonautics, space biology and medicine--a stage of even greater approximation of the most progressive branch of Soviet science--cosmonautics--with the concrete needs of public health care practice. In particular, problems dealing with in-depth investigation of forecasts of health status and work capacity of cosmonauts, introduction of appropriate measures to public health practice merit attention.

At the first plenary session, papers were delivered by P. V. VASIL'YEV and A. A. GYURDZHIAN--"Achievements of Aviation Medicine to Serve Practice,"

YE. A. KOVALENKO--"Basic Results of Studies of Oxygenation and Their Future Use in Public Health Practice," and G. P. PARFENOV--"Space Exploration From the Standpoint of Biology." All three papers, which were quite different in form and content, inspired much interest in the audience.

The subsequent work of the conference proceeded in the form of 16 section meetings and 3 symposiums, the brief contents of which are furnished below. At the concluding plenary session, R. M. BAYEVSKIY delivered a paper on the topic of "Methods of Forecasting Health Status of Cosmonauts and Their Use in Public Health Practice."

Section of 'Clinical and Physiological Research'

A significant part of the papers dealt with the condition of the cardiovascular system.

Several papers discussed methods of evaluating the state of the cardiovascular system, fluid-electrolyte metabolism, renal function and endocrine regulation by means of functional load tests, which are being introduced to clinical practice.

I. S. POLOZKOV et al. investigated central and peripheral hemodynamics as related to pulsed pressure factors applied to the lower half of the body, using special chambers and an anti-G suit for this purpose. This method has been recommended for clinical use. A. I. GRIGOR'YEV et al. submitted the results of using load tests developed for man, combined with simultaneous graded intake by mouth of sodium, potassium, calcium and magnesium salts. Studies were made of regulation of blood volume and renal function with the subjects in horizontal, antiorthostatic [head down] and orthostatic positions, submersion into immersion medium and exposure to LBNP [lower body negative pressure]. The role of ion loads, diet and motor activity was investigated. It was shown that the developed diagnostic procedures can be well-used in clinical practice.

In their paper, V. N. ORLOV et al. reported on the successful use for therapeutic purposes of "dry" immersion, which had been developed previously to simulate some of the effects of weightlessness (Ye. B. Shul'zhenko and I. F. Vil'-Vil'yams, 1976). This method has been used in the clinic at the Moscow Medical Stomatological Institute imeni N. A. Semashko for treatment of patients with edema of cardiac, renal and mixed origin. A comprehensive examination of 25 patients with marked edema syndrome revealed that sessions of "dry" immersion, lasting up to 6 h, have a marked and prolonged diuretic effect. Normalization of many functions was observed. It is considered promising to adopt the proposed method on a broad scale in public health practice.

Yu. M. NIKITIN, who was concerned with screening people for work in aviation and cosmonautics, demonstrated that it is possible to use ultrasonic Doppler cardiography to assess the functional state of arterial vessels of the cerebrum. A comparison was made of this technique to the results of cerebral angiography. As a result of examining 135 patients with cerebrovascular diseases, it was established that ultrasonic Doppler cardiography is of

great diagnostic significance, and it has been recommended for broad use in clinical practice.

The papers of A. S. TURETSKAYA and I. P. OSETROVA, as well as S. A. SKVORTSOV, demonstrated the efficacy of load tests for detection of early forms of cardiovascular disease in flight personnel.

Several papers (in particular, the one delivered by I. V. FEDOROV et al., and others) submitted new facts and hypotheses about the mechanism of functional change in the cardiovascular system under hypokinetic and orthostatic conditions, i.e., in states characterized by redistribution of blood.

BARAN'SKI et al. (Poland) submitted some interesting results of studies of the circulatory and respiratory systems during exposure to physical factors inherent in the work environment of pilots or cosmonauts. The authors developed equipment as a result of studying the transmissive function of the circulatory system, which is based on principles of feedback and closed control system. Using the proposed methods, it was shown that there are new possibilities for assessing the state of the cardiovascular system both at rest and with various load tests. The developed equipment and methodological approaches can be well-used both in clinical practice and sports medicine.

The paper of Doctor KLEIN et al. (FRG) evoked special interest; they studied central hemodynamics during exposure to spaceflight factors. We should mention the high informativeness of the methods used in their studies for catheterization of the chambers of the heart, which were used to assess the state of the cardiovascular system under simulated conditions. In a group of healthy subjects, hemodynamic changes were studied with simulation of weightlessness by keeping the body in antiorthostatic [head-down] position for 2 h at an angle of -6° followed by LBNP. Echocardiography (two-dimensional scanning and catheterization of veins along their course to the heart) was used, along with studies of pressure in the right atrium, right pulmonary artery, end pressure in pulmonary capillaries and cardiac output. The authors defined the most significant disorders that occur under the above conditions.

New findings pertaining to redistribution of body fluids and their deposition as related to spaceflight factors were reported by another team of authors from FRG (BAYSH, BEYER, GORDINSKI et al.). Using an original method they developed, a study was made of fluid redistribution under the effect of LBNP. A hypothesis was expounded for regulation of displacement of fluids from plasma into the interstitial space under LBNP conditions. A group of papers dealth with problems of stress in cardiology and space medicine.

An interesting paper delivered by MAKHO (CSSR), R. A. TIGRANYAN et al. (USSR) demonstrated the relevance of studying the state of the endocrine system to assessment of the stressogenic effects of factors that man is exposed to during short- and long-term spaceflights. In this paper, the results of examining animals after flights aboard the Cosmos series of biosatellites were also used. The authors demonstrated that combined changes inherent in stress are demonstrable during and after spaceflights. The generalizations they made are significant to public health practice.

B. A. PURINYA and V. A. KAS'YANOV demonstrated once more, on the basis of their findings, of the need and importance of a dialectical approach to assessment of man's performance, in particular, in studies of functions and structure of the cardiovascular system.

Several papers, including the reports of T. I. KRUPINA et al., discussed questions of screening scientist cosmonauts [researchers] for long-term spaceflights. They submitted the results of many years of investigations conducted with use of clinostatic and antiorthostatic hypokinesia, which defined a number of medical requirements for scientist-cosmonaut screening. The results of long-term spaceflights confirmed the validity of the suggestions they offered. The results of these studies are recommended for application to public health practice. They could serve as the basis for development of preventive and health-improving measures for healthy people whose motor activity is limited, as well as patients who must maintain bed rest for a long time because of the nature of their illness.

There was an interesting paper concerned with the prospects of refining the system of rendering medical care during manned spaceflights; it was authored by V. V. BOGOMOLOV and I. B. GONCHAROV. Some of the methodological approaches to working out anesthesiological care during flights merit attention. Several suggestions concerning refinement of drug therapy could be used in preventive medicine.

The paper of T. D. VASIL'YEVA et al. shed light on the results and implications of development of recovery measures for use in the postflight period after long-term space missions.

I. V. KONSTANTINOVA et al. reported on the prospects of using a system of diagnosing the early stages of decline in man's immunological reactivity, which was developed and tested by the authors on extensive clinical and experimental material, in space and clinical medicine for preventive purposes. It was shown that there is a correlation between different changes in state of the immunity system and early stages of diverse diseases.

In his paper, I. P. NEUMYVAKIN reported on the results of work on sorption purification of human blood and lymph in cases of exogenous and endogenous poisoning, which were obtained by means of a specially developed instrument. This technique is promising for use in clinical medicine. The paper ended with screening of a movie, which demonstrated the first success with this method under clinical conditions and in emergency medical practice.

Section of 'Psychophysiology'

Problems of psychophysiology occupied a large place in the program of the conference. A total of 23 papers were delivered at 4 section meetings by scientists from the USSR, People's Republic of Bulgaria, Republic of Cuba and CSSR, which dealt with theoretical and experimental studies of professional activity of cosmonauts, pilots, air traffic controllers, as well as individuals who participated in diverse laboratory and field (polar expeditions) studies simulating specific conditions (factors) inherent in aviation and cosmonautics. Among the papers delivered, great interest was inspired by reports on the

results of scientific-technical and experimental research conducted jointly by Soviet and foreign scientists on the Intercosmos program during the visiting expeditions to the Salyut-6 orbital station, with participation of scientist-cosmonauts from a number of socialist countries.

V. I. MYASNIKOV, O. P. KOZERENKO (USSR), K. ZLATAREV (People's Republic of Bulgaria), Ya. KHIDEG (Hungarian People's Republic) and a few other scientists assessed in their papers the mental activity of cosmonauts during the acute period of adaptation to weightlessness, on the basis of studies of time and precision characteristics of specified work, speed of simple and complex reactions, volume and rate of information processing (including work during exposure to audio interference), distinctions referable to perception of symbolic information, "sense of time" and nature of solving simple arithmetic and logic problems. They observed that, in spite of the decline of parameters of some mental processes and functions, the level of mental work capacity of cosmonauts remained high. This was apparently due to high motivation and mobilization of psychophysiological reserves to fulfill well the flight program.

The paper of V. I. MAKAROV was concerned with the principles of preparing work and rest schedules aboard the Salyut-6--Soyuz orbital complex during the period of interaction between the main expeditions (ME) and visiting expeditions (VE). He stressed that the rendez-vous with the VE was a highlight for the ME, with pronounced positive emotional coloration, powerful emotional charge, which extended its effect on the subsequent course of the ME flight. Experience in organizing man's life during a spaceflight could be followed to improve the efficiency of performance in the most varied areas: in industry, agriculture, transportation, sports and education.

The optimizing effect of VE on ME performance was developed in detail in the paper of O. P. KOZERENKO et al., on the example of using various types of information factors in the practice of psychological support of the crews of Salyut-6 orbital station. The set of measures of psychological support was found to be an effective means of compensation for the deprivation effects of the cosmonauts' specific habitat, as well as an effective means of preventing psychoemotional disturbances.

Development of psychoprophylaxis as a pressing problem of psychophysiology was discussed in the papers of O. P. KOZERENKO et al., B. I. PARMENOV-TRIFILOV et al., and B. M. STOLBUN. The speakers mentioned the high mental stress associated with the work of cosmonauts, pilots, air traffic controllers and management representatives. Considering the specifics of professional work of the group of individuals surveyed, they applied various principles to psychoprophylaxis, for example, psychological support based on psychological "reconstruction" of the habitat, making up for the shortage of social contacts, providing motivation for activity (O. P. KOZERENKO, V. I. MYASNIKOV et al.) or, on the contrary, psychological relief, as stressed in the paper of B. I. PARMENOV-TRIFILOV, O. N. BAKLUNOVA and V. F. GARSHENIN. The desirability of applying the psychological relief principle to assure the nervous and mental stability of controllers of automated air-traffic control systems is based by the authors on the distinctions of their professional work. As we know, controllers work under conditions with strict time limits and they must be ready to make decisions rapidly as the air situation changes.

Basing themselves on the results of prenosological identification of stress in management work, B. M. STOLBUN and A.V. KOLESNIKOVA stressed the need for broad use of the principle of psychoregulation. This conclusion was based on the results of studying background values of the tension index of workers at industrial ministries, which were close to the top of the normal range. The authors demonstrated a tendency toward development of arterial hypertension in the same individuals.

The paper of M. A. NOVIKOV et al. was concerned with theoretical validation and practical use in psychoprophylaxis of methods of voluntary self-regulation, which are based on the principle of biological feedback.

It is unquestionable that the principles expounded in the papers concerning psychoprophylaxis will find broad application, not only in aerospace medicine, but other areas of human endeavor under extreme conditions (submersion under water, spending winters at high latitudes, long-term life in small groups under self-contained conditions, etc.).

Several papers discussed the engineering psychological aspects of optimizing the professional performance of operators (cosmonauts, pilots). Great interest was shown in the paper of K. ZLATAREV (People's Republic of Bulgaria) dealing with the study of pilots' resistance to stress, as well as that of I. SHULTZ (CSSR) about operational psychophysiological assessment of operators' work capacity in aviation and cosmonautics. A. P. NECHAYEV, V. P. SAL'NITSKIY and R. V. KOMOTSKIY discussed an approach to evaluation of reliability of operator performance referable to elimination of malfunctions in a control system. With regard to the probability of flawless assessment by an operator of the condition of checked elements (ratio of number of correct opinions about their condition to total number of checks of elements in a given inspection cycle), the authors stressed the importance of such an approach, not only for quantitative evaluation of operator reliability in a concrete system, but to find the means of altering the structure of a system in order to improve its reliability.

In the paper of Yu. V. KAMENSHCHIKOV, A. S. KONDRAT'YEV and V. V. CHUMAKOV, extensive material was submitted, which permits determination of the optimum range of light for the function of an operator's visual analyzer and its typical changes under complicated lighting conditions. The authors validated the need to optimize the illumination engineering characteristics of onboard information display systems, on the basis of consideration of opticophysiological and psychophysiological patterns of visual analyzer function over the entire range of lighting conditions during flight work.

Much interest was inspired by the paper of M. M. SIL'VESTROV and T. L. SHAKLEIN, which dealt with problems of optimum choice of stability and controllability characteristics of the pilot-automation equipment-aircraft system, on the basis of their conformity to threshold sensibility of the analyzer systems of a pilot, which receive information about flight status. The authors have proposed and tested under laboratory conditions a method of optimizing the aircraft control system, which makes it possible to select wisely the parameters of system equipment with due consideration of the psychophysiological characteristics of the operator.

The theses expounded in these papers may find practical applications in development of both aviation and space equipment, as well as other forms of modern technology.

The neurophysiological aspect of investigation of motivation, attention, intellectual and other mental functions was covered in papers delivered by scientists from the Republic of Cuba (Estaves, Penyalver, Trapaga, Agillar, Navarro), who used for this purpose modern equipment and methods of electrophysiological investigation. The value of such studies, which are related to the search for integral neurodiagnostic parameters (conditioned negative wave, evoked potential, etc.) of the functional state of the central nervous system lies in the fact that they can be used in both experimental and clinical practice.

The papers of B. S. ALYAKRINSKIY, S. I. STEPANOVA and a few other authors, who summarized studies in the area of space biorhytmology, prompted lively discussion. In their reports, there was validation of the need to make use of the findings in clinical practice. This idea was confirmed in the speech of M. P. ZABUTNYY, who demonstrated the significance of considering the circadian rhythm of constitutional sensitivity to improving the efficacy of reflexotherapy methods. A. I. SHCHUKIN demonstrated this link on the example of institution of preventive measures against fatigue in individuals working on different shifts.

In conclusion, we must stress the high level of activity among participants of this section, who appealed for continuation of the practice of joint scientific research with foreign scientists and specialists. It was shown that development of such contacts is effective on the example of successful fulfillment of the Intercosmos program with regard to matters pertaining to the study of mechanisms of psychological adaptation, performance of human operator in aircraft or spacecraft control systems, expert determination of work capacity and psychoprophylaxis of adverse effects of occupational conditions (factors) on man's mental status and work capacity.

Section of 'Hygiene'

At meetings of this section, 14 papers were delivered, which dealt with the comprehensive description of the gas atmosphere of habitable pressurized compartments, hygienic evaluation of various polymers used in construction, hygienic aspects of the habitat environment, problems of microbiological status of cosmonauts and optimization of microflora of the body.

The papers of V. P. SAVINA et al., V. M. ZINOV'YEV et al. dealt with scientific validation of setting standards for levels of trace chemical contaminants in the air environment, which reflects complex interactions between the body and the environment. There was validation of methods of calculating maximum permissible concentrations (MPC) of deleterious impurities in the gas environment of sealed premises. The calculation methods proposed by V. M. Zinov'yev et al. are used to set tentative MPC for compounds in the gas atmosphere of sealed compartments.

Much interest was displayed in the paper of A. V. SEDOV et al., which was concerned with forecasting the rate of elimination of products of vital functions from the human body during exposure to extreme factors. Using correlation and regression analysis, as well as electronic computers, equations were obtained that show the rate of elimination of anthropotoxins as a function of intensity of physical labor, barometric pressure, ambient temperature and carbon dioxide level in inhaled air.

Use in practice of the results of these studies would permit forecasting the air environment of sealed compartments because of possible accumulation of toxic trace impurities and, consequently, to develop measures to improve it. In particular, the study of the rate of gas elimination would provide base data for development of methods of purifying the air environment.

O. A. SUKHORUKOV devoted his paper to the problem of formation of the set of trace impurities in an artificial atmosphere. He validated and proposed methods of monitoring the composition of trace impurities. The proposed methods have been tested experimentally and can be used to monitor the composition of artificial atmosphere, not only in spacecraft, but analogous engineering installations (pressure chambers, manned submarines [or underwater habitats] for oceanological research, etc.), which would yield a significant economic and social effect in a number of sectors of the national economy.

Several papers discussed toxicology of polymers, toxicity of products of combustion of materials and their biological stability.

A. L. YERMAK et al. submitted data on development of criteria for certifying nonmetal materials with respect to safety of their use in structural elements of items with consideration of accident situations. A complex criterion of "safe permissible saturation" (SPS) was proposed to assess toxicity and flammability of materials, which makes it possible to calculate the "critical mass of material" (CMM). Determination has been made of temperature of maximum toxic gas emission for materials based on tetrafluoroethylene and hexafluoropropylene copolymer, as well as material based on polycaproamide.

Much interest was evoked by papers concerned with microbiological aspects of spaceflights.

S. N. ZALOGUYEV and A. N. VIKTOROV reported the results of treating healthy carriers of pathogenic staphylococcus in order to prevent infectious diseases among individuals working in sealed rooms. The complex method proposed by these authors for treatment of carriers of pathogenic staphylococci was found effective under both ordinary living conditions and in sealed rooms.

V. M. SHILOV et al. reported the results of a study of sensitivity to antibacterial agents of conditionally pathogenic microorganisms isolated from cosmonauts before and after spaceflights of different duration. On the basis of the results of these studies, the authors developed recommendations for outfitting onboard medicine chests with effective antibacterials.

N. N. LIZ'KO et al. submitted the results of a study of the distinctions of the intestinal microbiocenosis of cosmonauts at different stages of preflight

[tr]aining and after short-term spaceflights. These authors, together with the [Go]rkiy Scientific Research Institute of Epidemiology and Microbiology, RSFSR Ministry of Health, developed and introduced to the practice of medical support of spaceflights the product, bifidumbacterin in tablet form, which is used to prevent dysbacteriosis of the intestine during spaceflights.

G. [.]. GONCHAROVA et al. devoted their paper to theoretical and practical aspects of developing and using new forms of bifidumbacterin. In particular, they have proposed a sour milk product using a specially matched strain of bifidobacterium as starter [ferment], as well as lyophilized foods enriched with bifidobacteria, which could find wide application both for medical support of spaceflights and public health practice.

The conference participants who were involved in discussions gave a high rating to the practical and theoretical importance of many papers. The wish was voiced to unify [standardize] laboratory methods of analyzing the products of polymer combustion.

Section of 'Biology'

This section held three meetings. A total of 28 papers were delivered and discussed, including 21 from the USSR, 1 from CSSR, 1 from the People's Republic of Bulgaria, 2 from France, 2 joint papers prepared by USSR and GDR specialists and 1 joint paper written by specialists of the USSR and Hungarian People's Republic. Twenty papers dealt with the effects of dynamic spaceflight factors on the body and eight, with problems of radiobiology.

Special mention should be made of papers devoted to such basic problems of space biology as the effects of weightlessness (G. P. PARFENOV, U. PLANEL' et al., A. V. SMIRNOVA et al.) and high-energy particles of galactic cosmic radiation (S. V. VOROZHTSOVA et al., GOBE et al., V. N. GERASIMENKO et al.) on intracellular processes of vital function. The results of experimental and theoretical analysis of this problem revealed that there are no serious biological restrictions at the present time that would be imposed on further penetration of man into space. Nevertheless, in spite of the optimistic predictions, the papers are indicative of a need to pursue further, more refined and, perhaps, more original research in order to comprehend the mechanisms of direct and mediated effects of dynamic and radiation factors of spaceflights on living systems, as well as to develop appropriate means of protection and prevention.

Papers that submitted the results of studies of animals on the systemic and organic levels also conformed to the slogan of the conference, since the parameters they contained provided the theoretical foundation for further improvement of the system of medical support of manned spaceflights. We refer to the data obtained from studies of the effects of weightlessness on behavior (Z. I. Ananasenko et al.), biorhythms (GEKHT et al.; V. Ya. KLIMOVITSKIY et al.), physiological properties and molecular composition of myofibril proteins of skeletal muscles (S. A. SKURATOVA et al.), metabolism (Yu. I. KONDRAT'YEV et al.), bone tissue metabolism in animals (V. Ye. NOVIKOV), etc.

There were also some important data on the effects of ionizing radiation on blood (V. N. GERASIMENKO and R. D. GOVORUN) and catecholamine levels in the hypothalamus (Ye. A. PROKUDINA et al.).

The experimental laboratory models, involving suspension of rats in unsupported position of the hind limbs (V. Ye. NOVIKOV) and clinostatic hypokinesia in primates (T. G. URMANCHEYEVA et al.), which were developed and introduced to research practice in the USSR, are of substantial interest, from the standpoint of possibility of studying physiological mechanisms of effects of weightlessness and development of preventive measures. These models open up new possibilities for solving a number of pressing problems of space biology through laboratory experiments with animals.

Several papers delivered in this section contained data on validation of the use of pantegem, pyracetam and corfadon for prevention of stress (L. C. POLEVOY et al.), as well as validation of use of diet and water with increased K content as radioprotective agents in cases of single and long-term exposure to radiation PRASLICKA and KHLEBOVSKI). Summation of radioprotective effects of cystamine or mexamine and hypoxic hypoxia, with a wide range of doses of gamma rays, has also been demonstrated (V. V. ANTIPOV et al.).

The results submitted at this section could be used to solve pressing problems of space biology and medicine, as well as in other areas of human endeavor.

Symposiums on 'Hypoxia' and 'Oxygenation of the Body'

Already at the first plenary session, Ye. A. KOVALENKO noted in his paper that problems of oxygenation were pressing, and that data obtained from investigations could be used in the future in public health practice. It was shown that various methods of studying oxygenation of the skin, mucous membranes and brain have already found broad application in clinical surgery, internal medicine, stomatology, pediatrics, neurosurgery, as well as functional diagnosis, in particular, in studies of regional blood flow volume and microcirculation in different organs and tissues.

V. B. MALKIN et al. discussed the main criteria of adaptation to hypoxia and prospects of future in-depth investigation of tissue adaptation. DAVIS, from the United States, delivered a big paper. His report dealt with problems of decompression disorders and use of hyperbaric oxygenation in the treatment of a number of diseases, in particular, gas gangrene and carbon monoxide poisoning. This paper prompted interesting discussion, in which Vadhavan, representing India, participated among others.

A. Yu. KATKOV and R. N. CHABDAROVA described new, promising methods of accelerating adaptation to hypoxia. The papers delivered by Cuban representatives--TRAPAGA, AGILLAR and ESTEVES--submitted new data on changes in mental functions and the electroencephalogram under hypoxic conditions.

I. N. CHERNYAKOV submitted the results of a comprehensive analysis of the effects on the body of excess pressure and rational means of its compensation.

A. G. ANTROPOV et al. commented in their report on the importance of indicators of tissue oxygenation to diagnosis of myocardial infarction and ischemic heart disease. P. V. BELOSHITSKIY demonstrated the role of hypothermia in the control of tissue hypoxia.

[illegible], representing Kabardino-Balkar University, who used unique methodological procedures, demonstrated for the first time in his interesting paper the changes in pO_2 and electrical activity of single neurons in the cerebral cortex of experimental animals in the presence of hypoxia and during the period of adaptation to it.

The papers of V. P. GALKIN and V. L. POPKOV discussed new methodological procedures for studying oxygen and carbon dioxide homeostasis.

At both symposiums, many questions were posed to speakers with reference to virtually all of the papers, and this lead to full-fledged, animated discussions. The symposiums were interesting and fruitful, having demonstrated that the problems being worked on are of interest to both aerospace medicine and public health care.

Symposium on 'Analyzer Physiology'

At this symposium, six papers were delivered and discussed. In their paper entitled "Use of Systems Approach to the Study of Spatial Orientation," G. L. KOMENDANTOV et al. observed that it is imperative to take into consideration the following factors (systems); properties of space (stimuli); analyzers that receive stimulus energy that is adequate for them; nervous processes reflecting the subject as a whole (its properties and traces of effects of similar stimuli in the past); righting reflexes that implement equilibrium function.

Interesting data about the distinctions of cosmonauts' vestibular reactions in short- and long-term flights were submitted by I. Ya. YAKOVLEVA et al. The paper of Ye. Ya. IL'INSKAYA summarized the results of comparative analysis of efficacy of electrostimulation and vibration in preventing vestibulo-vegetative disorders associated with the space form of motion sickness.

An original scientific conception of the role of "conjugate dominant states" in stabilizing the statokinetic functional system in the presence of seasickness was formulated in the paper of P. I. SYABRO. It was important that the efficacy of "conjugate dominant states" in motion sickness could be enhanced by use of pharmacological agents that do not impair reflex activity.

New aspects of interaction between analyzer systems and significance of the gas fixation reaction as a test of vestibular function were discussed in the paper of Yu. V. KREYDICH et al.

The paper of Yu. V. KRYLOV et al. dealt with some quantitative distinctions of auditory and nonauditory responses to man's continuous and long-term exposure to noise of moderate intensity, as related to the orbital phase of spaceflights.

G. L. KOMENDANTOV, I. B. KOZLOVSKAYA, T. A. NALIMOVA, Yu. V. KRYLOV and P. I. SYABRO participated in the interesting and meaningful discussion of the papers.

In his closing remarks at the end of the conference, O. G. GAZENKO noted its scientific fruitfulness and stressed that the data submitted in the

comprehensive papers justified entirely the conference's slogan, which refers to introduction of advances of space biology and aerospace medicine to public health practice. He cordially thanked all of the participants, in particular the foreign visitors, and appealed for continued collaboration to solve the most important problems of space biology and aerospace medicine.

* * *

The USSR High Degree Commission gave its approval to the following doctoral dissertations in the special field of "Space and Aviation Medicine":

BELKANIYA, G. S., "Functional Organization of Systemic Reaction to Earth's Gravity and Its Experimental Investigation" (Institute of Biomedical Problems, USSR Ministry of Health, 20 April 1979).

GRIGOR'YEV, A. I., "Regulation of Fluid-Electrolyte Metabolism and Renal Function of Man During Spaceflights" (Institute of Biomedical Problems, USSR Ministry of Health, 9 January 1981).

SHVETS, V. N., "Regulatory Influence of Lymphoid Tissue on Hemopoiesis Under Extreme Conditions (Institue of Biomedical Problems, USSR Ministry of Health, 9 January, 1981).

ABSTRACTS OF ARTICLES FILED WITH THE ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF MEDICAL AND MEDICOTECHNICAL INFORMATION

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AMMONIA CONTENT OF URINE AS RELATED TO TEMPERATURE AND STORAGE TIME

[Abstract of article by I. V. Yakimova, N. M. Nazarov and N. A. Golikova]

[Text] One of the main causes of diminished capacity of air filter for deleterious impurities in a sealed compartment could be the drastic increase in urine ammonia content when it is stored in tanks [collectors] of the sanitation system. This process is related, first of all, to breakdown of urea in urine, which occurs because of vital functions of microorganisms containing urease. For this reason, the main purpose of this study was to make a quantitative assay of ammonia released from nonpreserved urine under different storage conditions.

A study was made of the effect of urine storage temperature (20, 30, 40°C) on ammonia level in both unadulterated urine and urine contaminated with urobacteria.

Concurrently, determination was made of urine urea content, pH, as well as quantitative and qualitative composition of urine microflora.

It was demonstrated that, when unadulterated urine is stored at 20°C, there was only 26.6% decrease in urea content by the 30th day of storage, whereas ammonia level rose by 280%. Minimum ammonia content in urine was 2400 mg/ℓ (30 days). At 30°C, there was complete hydrolysis of urea in unadulterated urine by the 30th day of storage, while ammonia content increased by 927%. Maximum content was 6500 mg/ℓ.

When urine was stored at 40°C, urea level dropped by 80% by the 30th day of storage and ammonia level rose by 625%. Maximum demonstrable ammonia content was 4700 mg/ℓ.

Microbiological studies of unadulterated urine revealed that maximum quantity of microorganisms was found in urine at $t = 30°C$: $(6.3 \pm 0.28) \cdot 10^9$ cells/mℓ, and at all tested temperatures growth in number of bacteria was noted during the first 2 weeks, after which it became stabilized.

Typically, there were changes in qualitative composition of microflora in unadulterated urine during storage. Representatives of the genera Pseudomonas, Micrococcus, Escherichia and Citrobacter, which were demonstrable on the 1st day of storage, were replaced by Pseudomonas bacteria by the end of 1 month's storage.

In urine infected with typical urobacteria (Micrococcus ureae), the rate of urea hydrolysis was many times higher and within virtually the first 3 days about 70% of the urea was broken down. Complete hydrolysis of urea was observed by the 10th day of storage (20-40°C), and maximum ammonia content was in the range of 8300-12,500 mg/ℓ.

Thus, it was demonstrated that the quantity of ammonia in urine depends on storage temperature and time, as well as type of urine microflora.

3 illustrations, 8 references.

UDC: 612.273.2.017.2-06:612.391

EFFECT OF FASTING ON 'SPARE TIME' WHEN BREATHING WITH NITROGEN

[Abstract of article by A. Yu. Katkov, N. K. Loginova, S. I. Vol'vach, Yu. I. Pekhov, V. A. Steputenkov and Yu. B. Zolotareva]

[Text] Studies on 16 male subjects were pursued to test the effect of 15-day starvation, without restriction of water intake, on man's endurance of "instantaneous" form of hypoxia, which occurs when breathing with nitrogen.

The subjects' weight loss constituted 14% under the effect of 15 days of alimentary starvation. This was associated with decreased rate in propagation of ultrasound in bones, which is inherent in reduction of bone density, particularly over the long bones of the leg. Thus, while there was 350-400 m/s decrease in rate of propagation of ultrasound over the mandible under the effect of starvation, the decrease constituted 650-800 m/s for long bones of the leg. The "spare time" [or "time reserve"] when using nitrogen for breathing increased with statistical reliability from 75 ± 5.2 to 155 ± 18.1 s on the 15th day of the fast. In the control group of subjects, who were put on nitrogen breathing a second time, against a background of regular food intake, the "spare time" remained unchanged.

Rheoencephalography on the 15th day of the fast revealed diminished tonus of cerebral vessels when breathing with air and considerably less marked dilatation of these vessels during the test with nitrogen breathing than before the fast. Concurrently, on the 15th day of the fast there was an increase in number of capillaries in the nail bed per visual field. There was also a change in their reaction to hypoxia. Thus, while complete spasm of peripheral vessels of the finger developed before the fast, toward the end of the period

of nitrogen breathing, on the 15th day of the fast, in the same time interval, about half the nail bed capillaries remained per field, as compared to the findings when breathing with air.

On the 15th day of the fast, there was a statistically reliable decline in minute volume from 6.4±0.48 to 4.5±0.46 ℓ/min and oxygen uptake from 266±17.4 to 167±7.8 mℓ/min. There was also decline of ventilation reaction to hypoxia under the influence of fasting. While mean minute volume constituted 9.7±1.21 ℓ/min before the fast while breathing with nitrogen, on the 15th day of food deprivation it was only 5.7±0.92 ℓ/min. Toward the time when nitrogen breathing was stopped, both before and at the end of the fast, there was a decline of partial gas tension in alveolar air to about the levels: p_AO_2 dropped to 22-23 and p_ACO_2 to 24-25 mm Hg.

A new parameter was determined while using nitrogen for breathing--"oxygen output," which referred to the percentage of oxygen in exhaled air collected over the entire period of nitrogen period multiplied by the mean minute volume for the corresponding period. While this parameter constituted 520±80.4 mℓ/min before the fast, it was only 323±83.1 mℓ/min at the end of the fast, i.e., it declined substantially.

In all probability, it is expressly the decrease in oxygen uptake and slower ouput from the body as a result of diminished ventilation reaction to hypoxia that is the principal cause of the drastic increase in "spare time" with nitrogen breathing, under the influence of fasting.

2 tables; 11 references.

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